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TECTONICS OF THE SOUTH CASPIAN BASIN[1]

by

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The Caspian Sea is one of the best investigated basins in the world. The geologic structure of its floor and the pattern of distribution of recent sediments on it are rather well known.

The Caspian Sea basin has a definitely heterogeneous structure. The waters of the sea cover different tectonic elements of the first order: in the north, the southeastern part of the Precambrian Russian platform; in the middle, the epi-Hercynian (Paleozoic) platform; and in the south, the Alpine geosynclinal zone, within whose boundaries lies the entire South Caspian Sea.

Many works are devoted to the geologic structure of the floor of the South Caspian Sea. They discuss the geologic structure of the shallow areas and the problems of the relationship between the principal structural elements of the western and eastern shores.

In recent years, almost the entire South Caspian basin has been covered by pendulum and magnetometric surveys and the shallow areas of the Baku and Apsheron archipelagos and of the eastern littoral, by seismic surveys [3, 17]. Deep seismic sounding has been done along a profile from Kara-Bogaz-Gol in the direction of the Baku archipelago [5]. These areas have been studied also by other methods of marine geology: the sea floor has been mapped, investigations have been made by divers in the regions of bedrock outcrops and submarine mud volcanos, the sea floor has been photographed from the air and investigated by drilling, and so forth [2, 3, 8, 11, 14, 16].

The work provided a rather detailed picture of the geological structure of the nearshore areas of the sea floor to a depth of about 50 m, revealed a series of new submarine anticlines promising as oil structures, and located a number of submarine mud volcanoes, bedrock outcrops and other features.

But the deeper areas of the South Caspian sea remained uninvestigated and various views continued to exist on their geologic structure based on uncoordinated data and guesswork. It was believed that the South Caspian basin is bowl-shaped, with smooth slopes and a featureless flat bottom, that complex relief exists only along the shelf in the vicinity of the Baku archipelago and in the area to the west of Cheleken peninsula.

Random indications of shallow depths in the open parts of the sea were marked earlier on navigation charts. This made some geologists believe that a second submarine rise analogous to the Apsheron ridge stretches from Kirov gulf towards Chikishlyar [9].

Let us pass now to the factual data recently obtained by various investigators of the South Caspian and to the conclusions which follow from them.

The pendulum and magnetometric surveys covered a considerable part of the South Caspian basin. The densest network of stations is in its northern part, especially in the region of the Apsheron ridge, while the southern part of the basin south of the Lenkoran'-Chikishlyar line has remained unsurveyed.

Let us recall that the results of pendulum surveys in the sea north of the Apsheron ridge show 1) a region of mainly positive and weak negative gravity anomalies and 2) a region of sharp negative gravity anomalies. The boundary between these two regions lies in the sea to the east of Apsheron peninsula, approximately towards the middle of the Apsheron scarp, and then turns almost due east towards Krasnovodsk. The maxima of positive gravity anomalies are concentrated about the so-called Derbent maximum. The maxima of negative gravity anomalies in the second region are located in the area south of Neftyanyye Kamni. The negative gravity anomalies trend to the southeast from Apsheron peninsula to Cheleken and farther, to Nebitdag, outlining a deeply subsided area of the southeastern Caucasus and the Pribalkhansk depression.

[1]Sovremennaya tektonicheskaya struktura dna Yuzhnogo Kaspiya.

An airborne magnetometric survey showed that the boundary between the two areas of gravity anomalies coincides with the greatest magnetic anomalies.

At present it is generally acknowledged that the boundary between the two areas of gravity and magnetic anomalies has a geological meaning and separates the more stable epi-Hercynian platform from the mobile Alpine geosynclinal zone.

The data of deep seismic soundings along profiles from Kara-Bogaz-Gol towards the Baku archipelago indicate the following regularities [5]:

1. The depth to the crystalline basement or the conventionally granitic layer increases from northeast to southwest from 2.5 to 20 km.

2. The depth to the surface of the basaltic layer also increases in the same direction from 15 to 30 km. The maximum depths are located appriximately in the area of minimum gravity of 250 mgal lying to the south of Neftyanyye Kamni.

3. The thickness of the crystalline basement or the conventional granitic layer from its roof to the surface of the basaltic layer decreases from northeast to southwest, acquires intermediate properties (between granite and basalt) and gradually wedges out towards the Baku archipelago.

4. The thickness of the basaltic layer from the base of the crystalline basement to the Makhorovich discontinuity decreases considerably from Krasnovodsk towards Zhiloy Island.

5. The thickness of the earth's crust from the surface to the Makhorovich discontinuity increases in the same direction from 26 to 30 km.

These data show that the seismic parameters, and hence the structure of the earth's crust, change regularly in passing from the epi-Hercynian platform to the intermont depression of the Alpine geosynclinal zone. In particular, it may be concluded that the maximum thickness of sedimentary cover coincides with the gravity minimum located to the south of Neftyanyye Kamni.

Within the boundaries of the shallow water areas of the western and eastern shores of the South Caspian, seismic surveys, submarine drilling and other methods of marine geology have revealed the presence of previously unknown anticlines and established their connection with the corresponding anticlinal structures on the land.

In the north, in the part of the sea adjacent to Apsheron peninsula, lies the anticlinorium of the Apsheron archipelago. Beginning near the Dva Brata rocks, it trends towards Neftyanyye Kamni island and includes the following structures: the Dva Brata rocks, the Tsyuryupa and Apsheron banks, the Mardokyan rise and the adjacent sea, the Darwin bank, the North- and South Artemov folds, the Gyurgany rise and the adjacent sea and Zhiloy and Neftyanyye Kamni islands [11]. It undoubtedly continues to the southeast in the direction of the Cheleken peninsula.

To the southwest from the anticlinorium of the Apsheron archipelago, from Cape Zykh and Peschanyy island to the Makarov bank, lies an anticline which continues the Karachukhur-Zykh anticlinal axis.

The Baku archipelago is separated from the folded zone of the Apsheron marine area by an extensive gentle syncline plunging southeast and continuing the Dzheyran-Kechmass syncline of the southeastern part of Kobystan.

According to A.L. Putkaradze [10], G.G. Tumikyan and S. Ya. Rapoport [17] and others the great majority of rises in the Baku archipelago lie in definite belts, usually representing the seaward extensions of the folded zones of Kobystan and of the Kura lowland. These anticlinal zones are (Figure 3):

1) Bol'shoy Kyanizadag - Sangachaly - sea - Bulla - sea;

2) Alyatskoy ridge;

3) Pirsagat - Khamamdag - Svinoy island - Kamen' Ignatiya;

4) Kalamas - Byandovan - Kumani;

5) Pavlov banks - Pogorelaya Plita - Golovacheva - Kurinskaya;

6) Neftechala - Kurinskiy Kamen' island.

All these zones are separated by synclines.

Besides these anticlinal zones, a number of upwarps within the synclines have been found by seismic surveys. There is also a group of anticlinal zones on and off the eastern shore of the South Caspian Sea.

In the north, within the epi-Hercynian platform, lies the Kubadag-Bol'shebalkhan mega-anticline, and paralleling it to the south is the main tectonic trend of the Pribalkhan depression, which includes the Khudaydag, Monzhukly, Nebitdag, Koturtepe and Cheleken structures. This tectonic axis continues into the sea, forming such submarine structures as the Zhdanov, Gubkin, Livanov and Bezymyannaya banks [12, 14]. To the northwest it extends to the

anticlinorium of the Apsheron archipelago and is separated from the Kubadag-Bol'shebalkhan mega-anticline by the Kafal'dzha-Kel'kor syncline [13, 18].

The geological structure of the southern part of the West Turkmenian lowlands was studied by geophysical methods under the direction of Yu. A. Godin [6]. It was found that the anticlinal structures existing there trend nearly north-south, as was supposed by A.I. Kosygin [7].

On the basis of an investigation of the nearshore zone of this region, mainly of the mud volcanos and banks, we demonstrated that in the sea, in the vicinity of the Ul'sk bank and the submarine mud volcano (Gryazevoy), there are similar structures, also trending nearly due north. They are separated from the land structures by the extensive shallow Ogurchino-Kizylkum syncline, which may contain isolated upwarps similar to those found by seismic survey in the synclines of the Baku archipelago region [22, 23].

In the last two or three years the marine party of the Complex Southern Expedition of the Institute of Geology and Mineral Fuels of the Academy of Sciences, U.S.S.R., has obtained new data on the relief and structure of the floor of the South Caspian Sea [15].

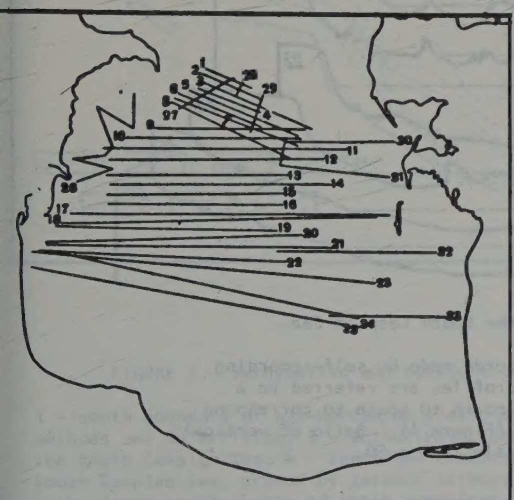

FIGURE 1. Bathymetric traverses (profiles) in the South Caspian Sea.

The bottom relief of the deep part of the South Caspian Sea was investigated by self-recording echo sounding apparatus giving a continuous bathymetric record (Figure 1). The data were used to construct bottom profiles (Figure 2) and bathymetric and tectonic charts (Figure 3). The investigation showed that the bottom relief of the South Caspian sea is extremely complex and provided entirely new information. Cores of deep sea sediments 4.5 m in length were taken from the summits and slopes of submarine ridges and the bottoms of depressions. Study of these cores throws light on the regularities of recent sedimentation and on its relation to the bottom relief of the South Caspian Sea.[2]

It is interesting to note that the depth records of the ridge summits are usually very clear and detailed, indicating the presence of bedrock outcrops and the absence of fine-grained recent muds, while the ridges slipes and especially the depressions give coarse and confused records, indicating the presence of thick deposits of fine-grained sediments. This is confirmed by the cores of the bottom sediments collected on summits and slopes and in the depressions.

The data on the relief of the shelf and continental slope of the South Caspian sea are summarized in Table 1. The profiles are numbered from north to south (from course 1 to course 25). The characteristics of relief are listed separately for the western and eastern parts of the sea. These data lead to the following conclusions:

1. The width of the shelf to the edge of the continental slope is not the same along the western and eastern shores. In the west it is narrow and averages about 43 km; in the east, it is much broader and averages 130 km.

2. Depth at the edge of the shelf varies in the different parts of the South Caspian Sea, ranging from 23 to 158 m. The average depth to the edge is much less in the west (85 m) than in the east (121 m). This is explained by the fact that the eastern part of the South Caspian Sea is at present subsiding more intensively than the western.

3. In both the western and eastern parts of the sea the depth of the shelf edge deviates strongly from the average for each of the shores (in the west the depth ranges from 23 to 158 m; in the east, from 32 to 150 m). This is due to the fact that the anticlinal trends of the land and the shallow nearshore zone of the western and eastern shores of the South Caspian Sea cut the shelf edge as they extend into the sea, pass through the continental slope and extend to the floor of the sea. The least depths over the shelf edge correspond to these submarine anticlines; the greatest depths, to the synclines.

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[2] The authors take this opportunity to express their deep gratitude to the commander of the hydrographic division of the Caspian fleet, Captain of the 1st rank V.L. Pisachenko, for his aid in this work.

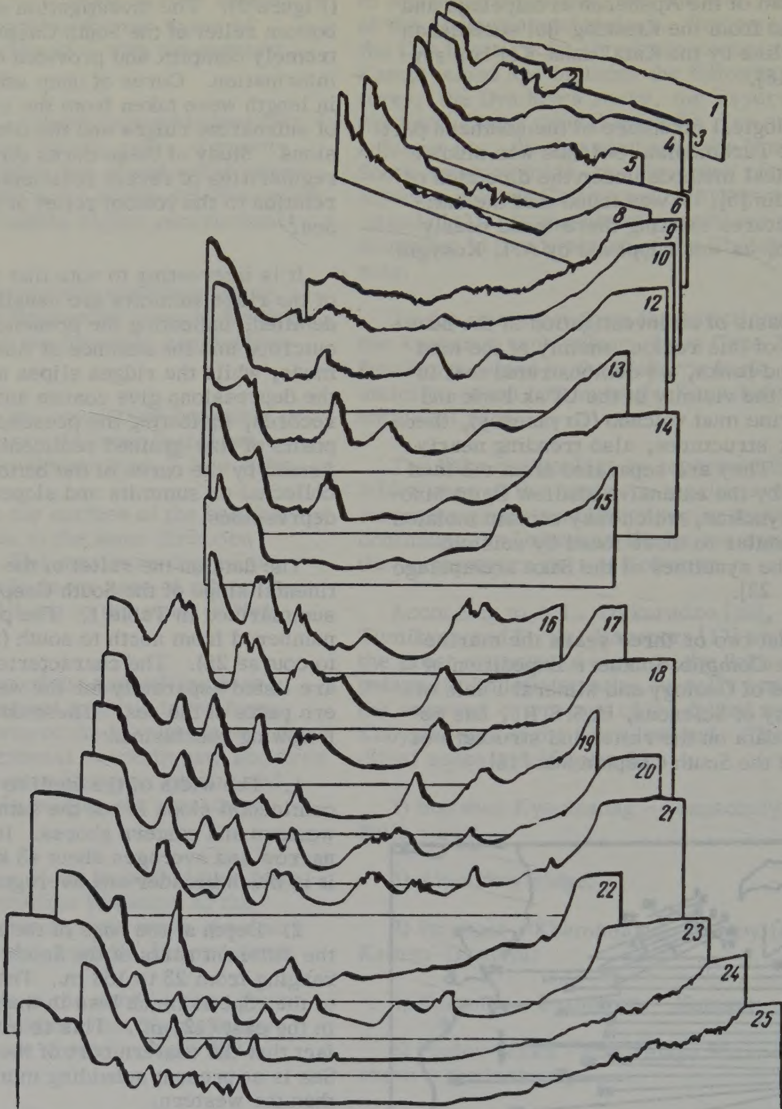

FIGURE 2. Bottom profiles of the South Caspian Sea.

Constructed from continuous records made by self-recording echo sounding apparatus. The profiles are referred to a meridian and are arranged from north to south to correspond with the sequence of traverses (Figure 1). Ratio of vertical to horizontal scale is 1 : 50.

Thus, the depth of the shelf edge is a very sensitive indicator or neotectonic movements and may, to a certain extent, serve as their measure. We noticed this for the first time while echo sounding the Apsheron ridge [12].

4. The depth over the shelf edge decreases in the direction of the Apsheron ridge and the Elburs Mountains and increases in the central part of the South Caspian Sea (except for the shallows over the anticlines). This indicates that the Apsheron ridge andthe Elburs Mountains areas are undergoing a more intensive relative movement than the middle part of the South Caspian Sea.

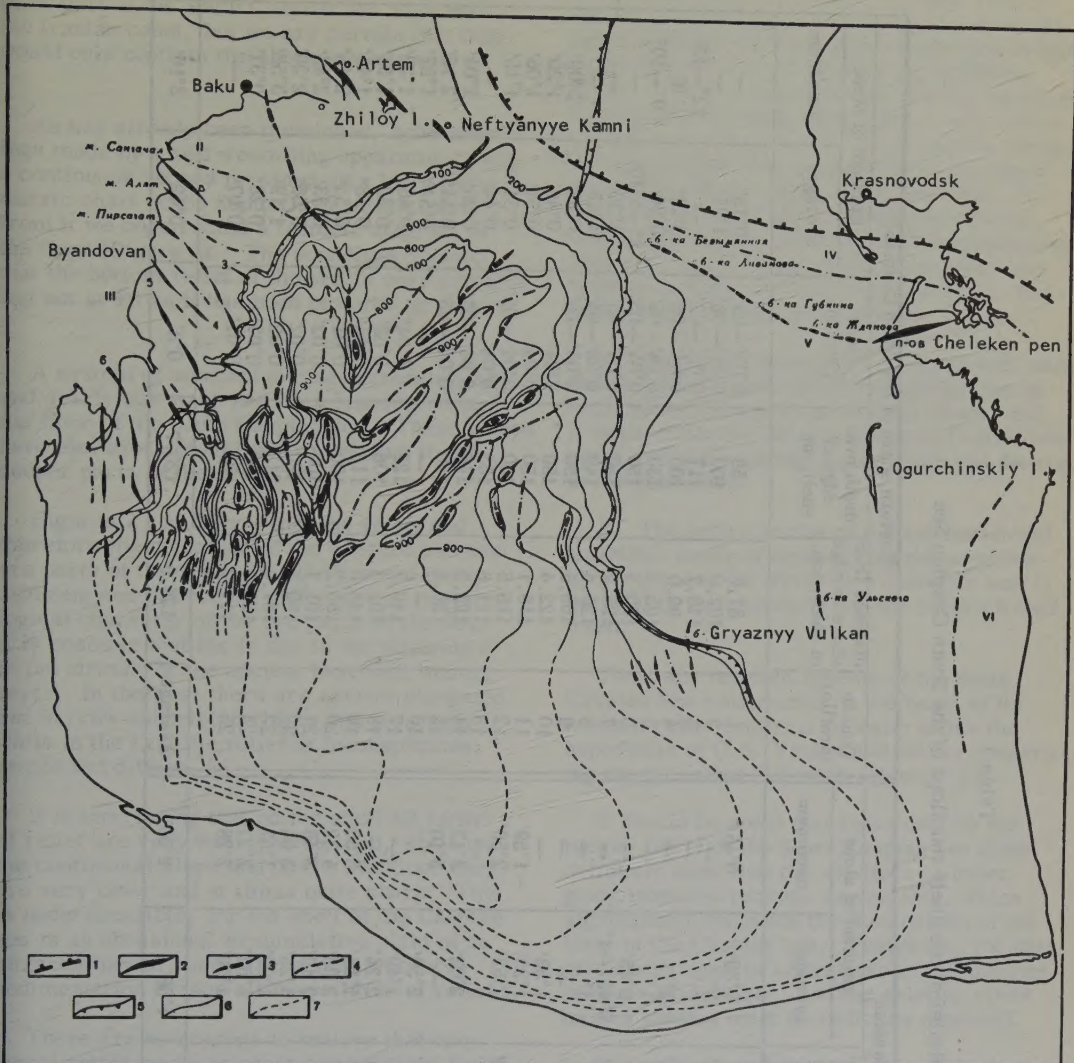

FIGURE 3. Bathymetric and tectonic chart of the floor of the South Caspian Sea.

1 - south boundary of epi-Hercynian platform; 2 - anticlines revealed by seismic and other methods and by drilling; 3 - anticlinal tectonic lines contributing to the floor relief of the South Caspian Sea; 4 - synclinal tectonic lines contributing to the floor relief of the South Caspian Sea; proved by seismic surveys in nearshore areas; 5 - edge of shelf; 6 - isobaths drawn on the basis of sonic soundings; 7 - isobaths drawn on the basis of navigation chart data.

Figures on the chart:

I - Apsheron archipelago anticlinorium; II - extension of the Dzheyran-Kechmass syncline into the sea; III - anticlinal zones of the Baku archipelago: 1 - Bol'shoy Kyanizadag - Sangachaly - Bulla - sea; 2 - Alyatsk ridge; 3 - Pirsagat-Khamamdag-Svinoy Kamen' island - Ignatius Island; 4 - Kalamas-Byandovan - Kumani; 5 - pavlov bank - Pogorelyy shallow - Golovacheva Kurinskaya; 6 - Neftechala - Kurinskiy Kamen' I.; IV - Kafal'dzha - Kal'kor synclinal downwarp; V - main tectonic line of Pribalkhan depression; VI - Ogurchino-Kizylkum syncline.

Table 1

Relief of the Shelf and Slope of the South Caspian Sea

Western shore of the South Caspian						Eastern shore of the South Caspian					
Course (profile)	distance from shore to edge of shelf, km.	depth over edge of shelf, m.	shelf gradient	gradient of slope		Course (profile)	distance from shore to edge of shelf, km.	depth over edge of shelf, m.	shelf gradient	gradient of slope	
	--	--		average	maximum					average	maximum
1	58,5	100	0°06′	0°30′	0°45′	1	87,0	58	0°02′—03′	0°15′	—
2	60,7	100	0°05′—06′	2°	—	2	102,0	100	0°01′—02′	1°21′	—
3	58,9	70	0°04′	2°	—	3	116,7	117	0°01′—02′	—	12°—13°
4	45,7	80	0°06′	1°	—	4	99,0	100	0°04′—05′	0°27′	8°
5	54,8	100	0°06′	1°	—	5	105,5	130	0°04′—05′	0°30′	9°—10°
6	37,0	65	0°06′	0°45′	—	6	120,4	150	0°04′—05′	1°—1°10′	—
7	43,5	60	0°04′—05′	0°45′—1°	—	7	125,9	140	0°04′—05′	1°30′	—
8	38,5	60	0°05′	1°	—	8	120,4	140	0°03′—04′	1°15′	—
9	—	—	—	—	—	9	109,3	150	0°04′—05′	0°52′	2°09′
10	—	—	—	1°53′	—	10	122,4	150	0°04′	0°49′	1°20′
11	—	—	—	1°30′	1°59′	11	118,1	150	0°04′	0°51′	1°06′
12	53,7	95	0°06′—07′	2°52′	2°56′	12	118,5	150	0°04′—05′	0°51′	1°15′
13	—	—	—		—	13	111,6	153	0°04′	0°44′	—
14	55,1	64	0°04′	2°02′	3°13′	14	122,2	146	0°04′—05′	0°39′	1°04′
15	—	—	—	—	3°10′	15	120,4	150	0°04′—05′	0°54′	2°15′
16	—	—	—	2°50′		16	—	—	—	0°51′	1°37′
17	—	90	—	1°49′	—	17	110,7	122	0°04′	0°46′	1°22′
18	22,2	80	0°12′—13′	2°24′	—	18	191,3	106	0°02′	0°42′	1°35′
19	—	92	—	1°38′	3°50′	19	115,0	115	0°04′	0°58′	1°41′
20	48,2	137	0°10′	2°23′	4°32′	20	185,2	100	0°01′	0°54′	2°15′
21	48,2	158	0°11′	2°19′	3°48′	21	191,1	105	0°02′	0°53′	2°43′
22	27,8	80	0°09′	1°25′	3°04′	22	190,7	120	0°02′	0°50′	2°20′
23	16,9	80	0°06′	1°02′	1°57′	23	187,0	112	0°02′	1°19′	3°52′
24	—	—	—	1°52′	2°21′	24	126,0	100	0°02′	0°28′	0°31′
25	13,9	23	0°05′—06′	1°10′	2°28′	25	111,2	32	0°01′	0°07′	—
Average	42,7	85,2	0°06′	1°38′	2°50′	Average	129,9	120,7	0°3′	0°49′	3°10′

Note: Comma represents decimal point.

Unfortunately we have no data on the southern-nost part of the South Caspian Sea adjacent to he Iranian coast, but we are certain that they vould only confirm the above statements.

As has already been mentioned, echo sound-ngs made by a self-recording apparatus giving continuous record provided data for a bathy-netric chart of the South Caspian sea, and rom it we constructed a tectonic diagram of he floor (Figure 3). The soundings showed hat the bottom relief of the sea is very complex ind not at all as it has been pictured up to now.

A system of submarine ridges trending due ind nearly due south has been discovered on he floor of the South Caspian Sea. These ridges iave elevations of 400-500 m relative to the leeper parts of the sea floor.

Figures 2 and 3 show that the relief and herefore the structure of the western and east-ern parts of the South Caspian Sea are quite lifferent and reflect the difference in the geo-ogical character of the two parts of the sea. t is possible that his is due to the difference n the attitude of the ancient basement and its lepth. In the west there are narrow elongated ind narrow submarine ridges and trenches, vhile in the east the relief is inconspicuous, gentle and diffuse.

It is interesting that on the shelf all forms of relief are very weakly developed, while on he continental slope and on the sea floor they ire very clear and at times quite sharp. This s understandable, for the shelf of the Caspian sea is an abrasional-accumulative plain of an ntracontinental basin where very intensive sedimentation erases all inequalities of relief.

There are no reasons to believe that ero-sional relief exists at great depths in the South Caspian Sea. The geological history of the sea, at least in the Tertiary and Quaternary eriods, speaks against its existence. We may onsider that in the deep parts of the sea the elief is primary, the ridges corresponding to nticlinal structures and the depressions to the ynclinal. Moreover, considering that in the Kura lowland there are structures which are ctive at present, it may be assumed that simi-ar upwarping is going on on the sea floor. As s shown by the appended tectonic chart of the outh Caspian Sea (Figure 3), almost all anti-clines and synclines discovered by echo sounding re continuations of the corresponding anticlinal ones of the Apsheron marine sea, Kobystan ind the Baku archipelago in the west and of the nticlinal zones of the West-Turkmenian plain n the east.

The general pictureis as follows: the anti-clinal structure of the Apsheron archipelago in the west and the principal tectonic axes of the Pribalkhan depression in the east probably join en echelon in the extensive depression lying in front of the central part of the Apsheron scarp. These tectonic trends and the structures to the south of them, lying both on land and in the shallow sea, give rise to structures which, trending southward, gradually acquire more and more definite north-south direction. It has already been mentioned that we have no data on the southernmost part of the South Caspian Sea, and it is not clear, therefore, how their structures join the Elburs system. Evidently there are two possibilities:

1. A deep frontal downwarp filled with sediments derived from the Elburs Mountains extends along the southern Caspian shore, and it is possible that the submeridional anticlines described above plunge to the south and die out in the downwarp.

2. The entire series of the submeridional anticlinal zones in approaching the southern shore changes its strike to a direction nearly parallel to the shoreline and the Elburs Range itself.

Thus, the tectonic scheme of the South Caspian Sea constructed on the basis of its modern relief confirms to some extent the hypothesis of O.S. Vyalov and others concerning the so-called "Caspian sygmoid" [4].

It should be noted that these data on the bottom relief of the South Caspian Sea quite definitely show that the sea floor is undergoing intensive tectonic movements, which significantly influence the fluctuations of the level of the Caspian Sea. Therefore, the data given here must be considered in discussions of these fluctuations, and the existing views on this subject must be radically modified.

In conclusion we express our thanks to Academician A.L. Yanshin for valuable comments on our work.

REFERENCES

1. Apresov, S.M., Neftenosnost' yugozapadnoy pribrezhnoy podvodnoy polosy Kaspiyskogo morya [PETROLEUM RESERVES OF THE SOUTHWESTERN NEARSHORE SUBMARINE BELT OF THE CASPIAN SEA]: Aznefteizdat, 1933.

2. Aerologicheskaya s"yemka melkovodnykh zon Kaspiyskogo morya [AERIAL SURVEY OF THE SHALLOW WATER ZONES OF THE CASPIAN SEA]: Izd. Akad. Nauk SSSR, 1958.

3. Vartanov, S.P., V.A. Kornev and Yu.G.

Yurov, Rezul'taty seysmorazvedochnykh rabot po profilyu Cheleken - Neftyanyye Kamni [RESULTS OF SEISMIC PROSPECTING ALONG THE LINE: CHELEKEN - NEFTYANYYE KAMNI]: Geol. nefti i gaza, no. 4, 1959.

4. Vyalov, O.S., O mezozoidakh v Azii [MESOZOIC STRUCTURES IN ASIA]: Doklady, Akademiya Nauk SSSR, t. 16, no. 2, 1937.

5. Gagel'gants, Ye.I. Gal'perin, I.P. Kosminskaya and R.M. Krakshina, Stroyeniye zemnoy kory tsentral'noy chasti Kaspiyskogo morya po dannym glubinnogo seysmicheskogo zondirovaniya [STRUCTURE OF THE EARTH'S CRUST IN THE CENTRAL PART OF THE CASPIAN SEA ACCORDING TO THE DATA OF DEEP SEISMIC SOUNDINGS]: Doklady, Akademiya Nauk SSSR, t. 123, no. 3, 1958.

6. Godin, Yu.N., N.P. Luppov, Yu.I. Sytin and P.K. Chikhachev, Osnovnyye osobennosti tektonicheskogo stroyeniya territorii Turkmenskoy SSR [MAIN FEATURES OF GEOLOGIC STRUCTURE OF THE TURKEMNIAN SSR]: Sov. geologiya, sb. 1, 1958.

7. Kosygin, A.I., Gazovyye mestorozhdeniya i gazovyye vulkany Turkmenii. V sb. Prirodnyye gazy [NATURAL GAS AND GAS VOLCANOS OF TURKMENIYA. IN COLL.: NATURAL GASES]: Vyp. 4-5, 1932.

8. Mirchink, M.F., Neftyanyye mestorozhdeniya Azerbaydzhana [PETROLEUM DEPOSITS OF AZERBAYDZHAN]: Gonti, 1939.

9. Putkaradze, A.L., K istorii geologicheskogo razvitiya Yuzhnogo Kaspiya [GEOLOGIC HISTORY OF SOUTHERN CASPIAN SEA]: Doklady Akademiya Nauk AzerbSSR, t. 11, no. 1, 1955.

10. __________, Bakinskiy arkhipelag [BAKU ARCHIPELAGO]: Aznefteizdat, 1958.

11. Solov'yev, V°F°, Tektonicheskaya skhema Priapsheronskogo rayona. V kn. Pervaya nauchno-tekhn. konf. Nauchn. stud. ob-va Mosk. neft. in-ta [TECTONICS OF THE APSHERON REGION. IN THE BOOK: FIRST SCIENTIFIC AND TECHNICAL CONFERENCE OF THE STUDENT SCIENTIFIC SOCIETY AT THE MOSCOW PETROLEUM INSTITUTE]: 1947.

12. __________, Rel'yef i stroyeniye Apsheronskogo poroga [RELIEF AND STRUCTURE OF THE APSHERON RIDGE]: Izvestiya. Akademiya Nauk, SSSR, ser. geol., no. 5, 1954.

13. __________, Nekotoryye voprosy tektoniki Kaspiyskogo morya [SOME PROBLEMS OF THE STRUCTURE OF THE CASPIAN SEA]: Tr. Soveshch. po tektonike al'piyskoy geosinlinal'noy obl. yuga SSSR. Izd. Akad. Nauk AzerbSSR, 1956.

14. __________, and L.S. Kulakova, Geologicheskoye stroyeniye i persepktovy neftenosnosti podvodnogo sklona vostochnogo poberezh'ya Yuzhnogo Kaspiya [GEOLOGICAL STRUCTURE OF THE SUBMARINE SLOPE OF THE EASTERN SHORE OF THE SOUTH CASPIAN SEA AND ITS PETROLEUM POTENTIALITIES]: Tr. in-ta geol. Akad. Nauk TurkmSSR, t. 1, 1956.

15. Solov'yev, V.F., L.S. Kulakova and G.V. Agapova, Gornyye khrebty na dne Yuzhnogo Kaspiya [MOUNTAIN RANGES ON THE FLOOR OF THE SOUTH CASPIAN SEA]: Priroda, no. 8, 1958.

16. Suleymanov, D.M., Podvodnyy sklon poberezh'ya Kaspiyskogo morya mezhdu Apsheronskim poluostrovom i zalivom imeni S. M. Kirova [SUBMARINE SLOPE OF THE CASPIAN SHORE BETWEEN APSHERON PENINSULA AND S.M. KIROV BAY]: Izd. Akad. Nauk AzerbSSR, 1953.

17. Tumikyan, G.G. and S.Ya. Rapoport, Tektonika Bakinskogo arkhipelaga v svete dannykh seysmorazvedki [TECTONICS OF THE BAKY ARCHIPELAGO IN THE LIGHT OF SEISMIC SURVEYS]: Novosti neft. tekhniki, ser. geol., no. 4, 1957.

18. Khain, V.Ye., A.N. Shardanov, V.F. Solov'yev and B.V. Grigor'yants, Tektonicheskoye polozheniye Apsheronskogo poluostrova v sisteme Bol'shogo Kavkaza [TECTONIC POSITION OF THE APSHERON PENINSULA IN THE GREATER CAUCASUS SYSTEM]: Izvestiya, Akademiya Nauk SSSR, ser. geol., no. 1, 1955.

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THE POSITION OF GRANITE GNEISSES AND GRANITES IN THE STRUCTURE OF THE SOUTHERN ULUTAU (CENTRAL KAZAKHSTAN)[1]

by

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In the author's opinion the granite gneisses, gneisses and felspathized rocks of the Southern Ulutau were formed as a result of granitization of the Lower Proterozoic rocks. The paper discusses the distribution of granite gneisses and granites and certain textural characteristics of the granitized rocks dependent on their position in the folded structure.

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Introduction

Granites and granite gneisses are widespread among Precambrian rocks which had been subjected to folding and metamorphism. The mineralogical, petrographic and geochemical features of granitization, the migration of matter and the sequence of metasomatic changes in rocks of this type are well known at present. Less well known is the tectonic pattern of distribution of metasomatic granites. The information on this subject is usually limited to a statement that the processes of granitization are related in time to intensive tectonic activity.

The characteristics of distribution of granites, granite gneisses, gneisses and feldspathized rocks in different tectonic settings are well illustrated in the area of Proterozoic rocks in the Southern Ulutau. As a result of many years of work by N. A. Shtreys and by a group of geologists of the Geological Institute of the Academy of Science under his direction (M. S. Markov, A. L. Knipper, T. G. Pavlova), the Proterozoic rocks of this region have been subdivided in detail and the main features of their structure ascertained.

Stratigraphy and Tectonics of the Region

In the Proterozoic section of the southern Ulutau, the following Precambrian series of Central Kazakhstan have been identified: (top to base) the Borovsk, the Karsakpay (Akdymsk) and the Yerementau [5]. The Borovsk series is referred to the Lower Proterozoic and includes the Dyusembay and the Turmurzin formations [7]. The lower, Dyusembay formation is composed of porphyritic lavas and subordinate quartz-mica schists, feldspathic quartzites and granular quartzites. The Tumurzin formation contains graphitic quartzites at the base and is characterized by a great variety of schists and quartzites. In the sections of this formation exposed in synclines, green schists with limestone lenses and graphitic quartzites predominate, while in anticlines fine-grained feldspathic quartzites are widespread and green schists are much less abundant. An angular and azimuthal unconformity separates the Dyusembay and the Tumurzin formations. The metamorphic rocks in both formations are of the green schist rank. The total thickness of the Borovsk series is 3200 - 3500 m.

The Upper Proterozoic Karsakpay and the Sinian Yerementau series contain disconformities and angular unconformities and are divided into a number of formations composed mainly of basic and acid flows and pyroclastic rocks. At the base of the Karsakpay series lies the Sarysay rhyolite formation, which includes conglomerates containing pebbles of granitized rocks.

Only in the Borovsk series did local recrystallization and feldspathization produce various rocks gradually changing from porphyroids, schists and quartzites into genisses and granite gneisses. Granites, syenites and diorites are also present in the region.

The rocks of the Borovsk series form the Maytyuba anticlinorium 20-25 km wide and trending to the north for 150 km. In the east it adjoins the Karsakpay synclinorium formed by the rocks of the Karsakpay series, and in

[1]Polozheniye granito-gneysov i granitov v strukture Yuzhnogo Ulutau (Tsentral'nyy Kazakhstan).

the west, the Baykonur synclinorium composed of Lower Paleozoic rocks. The eastern boundary of the anticlinorium is complicated by longitudinal north-south faults, but in general it preserves the normal stratigraphic sequence. The structure of the western side of the anticlinorium is more complex, because, besides being broken by faults, the Upper Proterozoic section contains numerous long hiatuses. The section is considerably shortened and is transgressively and unconformably overlain by the Lower Paleozoic rocks. To the north and south, where the anticlinorium plunges beneath the younger superimposed Paleozoic structures, there are east-west and diagonal faults.

Further structural description will be confined to the 75 km long central part of the Maytyuba anticlinorium, for it is there that granitized rocks and granite gneisses are found (Figure 1). The central part of the anticlinorium is bounded in the northwest by a fault zone with superimposed Middle Paleozoic synclinal basin. In the northeast a large syncline composed of the rocks of the Tumurzin formation separates the central part from the peripheral anticlinal zone (Figure 1, P. a.). At the southern nose of the anticline the boundary is drawn along a diagonal fault. In the west and east the boundaries of the central part and of the anticlinorium in general coincide.

The central part of the anticlinorium is characterized by the predominance of anticlinal over synclinal structures. The anticlinal zones, following one another northward, form a western and an eastern belt separated by a large syncline. The en echelon anticlines within the anticlinal zones are separated by very small synclines. The best formed is the northwest trending syncline separating the northern and middle anticlines of the western zone. The folds of the western anticlinal zone are slightly assymmetrical with steep western limbs

FIGURE 1. Geological map of the central part of Maytyuba anticlinorium.

1 - Middle Paleozoic deposits; 2 - Lower Paleozoic deposits; 3 - Karsakpay series; 4 - acid effusives of the Sarysay formation; 5 - quartzites and schists of the Tumurzin formation; 6 - porphyroids and schists of the Dyusembay formation; 7 - diorites; 8 - syenites; 9 - granites; 10 - granite gneisses; 11 - rocks of the Tumurzin and Dyusembay formations granitized into gneisses; 12 - large and small faults; 13 - anticline and syncline axes; 14 - attitudes of rocks.

Figures on the map:

I - Western block; II - Central block; III - Northern block; F.a. - southern termination of peripheral anticline.

45 - 30° dips) and gentler eastern limbs (30 - 10° dips).

The structure of the eastern anticlinal zone is very asymmetrical. The western limbs of the anticlines are overturned to the west or have very steep dips, while the eastern limbs have lower dips (25 - 45°). The northern anticline has a similar structure but a steeper dip to the east (up to 55°) and a very steep plunge to the north.

An important role in the structure of the anticlinorium is played by faults striking north to northwest and breaking it into a number of blocks (Figure 1, I — III). The entire western anticlinal zone is a block containing a very incomplete section of the Karsakpay series in its western part. This indicates that the block stood high for a long period of time. The eastern block includes a large syncline and the eastern anticlinal zone complicated by a series of northwest trending faults which are younger than the faults striking north. The eastern block contains both the Dyusembay and Tumurzin formations and the adjacent limb of the Karsakpay synclinorium has the most complete section of the Karsakpay series. Evidently the eastern block is lowered with respect to the others.

The northern block includes an anticline extending from the eastern anticlinal zone but shifted northwest with respect to it. Only small faults cut the northern block.

Gneisses and Granite Gneisses

In this section, rocks altered to various degrees as compared with the "primary" green schists will be discussed. The alteration consisted in recrystallization, feldspathization and formation of different gneisses including granite gneisses. In different parts of the region all varieties of rocks may be observed, ranging from the primary rocks to granite gneisses and from the latter to granites. The scarcity of injection gneisses and absence of migmatites are characteristic.

The recrystallized and feldspathized rocks are not equally well developed in all parts of the anticlinorium. In the western anticlinal zone and in the northern anticline granite-gneisses are widespread, but in the eastern anticlinal zone rocks of low metamorphic rank are predominant. The granitized area is delimited in the west by a belt of rocks of the Dyusembay formation with a sulphide-bearing quartzite at the base. In the north and east, altered rocks do not extend beyond the area occupied by the Tumurzin formation. In the south, in the subsided central part of the anticlinorium, the granite gneisses are covered by the rocks of the Karsakpay series and Middle Paleozoic deposits.

Granitization affected the rocks of the Dyusembay and Tumurzin formations. The least metamorphosed varieties of the porphyroids of the Dyusembay formation are light-colored bluish-gray, gray and brownish rocks with fine or coarse schistosity and porphyroblasts of quartz and feldspar. The quartz-mica schists are greenish finely schistose rocks composed of quartz and muscovite and, in some varieties, of feldspar and biotite.

Of the rocks of the Tumurzin formation, the feldspathic quartzites, quartz-biotite and two-mica schists, which form anticlinal structures, are metamorphosed. The feldspathic quartzites are massive, light pink or grayish rocks, composed of quartz and feldspar in varying proportions. The schists are finely banded, schistose and fine-grained, of very variable composition and appearance.

Without describing the process of granitization as a whole, we shall note only the characteristics of the different microclines in the recrystallized and feldspathized rocks. In addition to the primary potash feldspar in the blastoporphyritic rhyolites and in the granular groundmass of the porphyroids, two types of microcline have been observed in the granitized rocks.

1. The microcline replacing plagioclase and muscovite occurs as strongly kaolinized porphyroblasts, often enclosing relicts of plagioclase and muscovite. It contains small patches of perthitic albite and may show either a very sharp and fine grid structure or none at all. Sometimes the microcline is twinned on the Carlsbad law with both individuals exhibiting fine polysynthetic twinning (Figure 2).

2. The microcline of the second type occurs in lenticular monomineralic aggregates or as equidimensional grains disseminated through the rock. It is fresh, almost untouched by kaolinization and only slightly corrodes the plagioclase crystals. The plagioclase is sometimes included in the microcline porphyroblasts. This microcline exhibits either a slightly wavy extinction or a sharp coarse microcline grid (Figure 3). There are intermediate varieties but neither Carlsbad twins nor perthite has been found. The microcline of the first type is sometimes corroded by the microcline of the second type, which is therefore the later of the two.

The microcline of the first type is metasomatic and occurs in rocks which contained primary potash feldspar, but the microcline of the second type must have been introduced, for it is found in rocks containing no primary feldspar. The two types occur both together and separately. In the first case the sharpness of the microcline grid is very similar in both. The variations in the microcline structure are

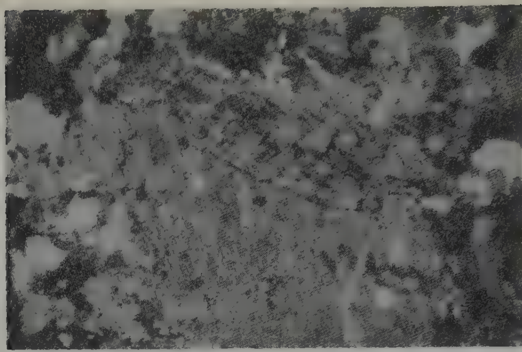

FIGURE 2. Metasomatic microcline in the rock. Crossed nicols, x 54.

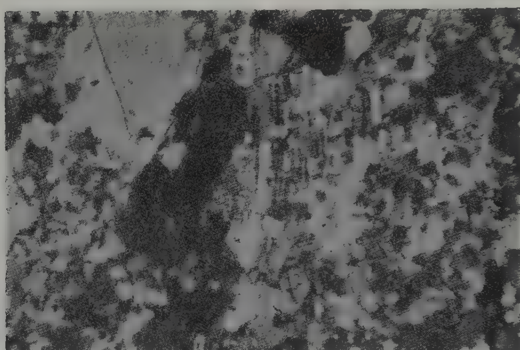

FIGURE 3. Injection microcline. Crossed nicols, x 54.

evidently related to the different stages of ordering of its lattice in the process of transformation from the monoclinic to the triclinic symmetry [3]. This is accompanied by a change in the optical orientation of the mineral and an increase in 2V from 72 - 74° to 80 - 88°.

The strong development of microcline porphyroblasts is characteristic of granite gneisses. These rocks range from leucocratic to those containing a considerable amount of dark minerals, from massive to strongly gneissoid and from medium-grained to coarse-grained porphyritic rock. The differences in the mineralogical composition and texture of the original rocks are reflected in the granite gneisses but in subdued form.

The texture of the granite gneisses is usually inequigranular. Large microcline porphyroblasts alternate with fine-grained aggregates of quartz and feldspar and segregations of various dark minerals.

The granite gneisses pass into granites gradually and on the map the boundary between the two rocks is drawn arbitrarily through those points where the gneissoid structure of the granite gneisses fades into equigranular and massive granitic structure. The granites are relatively uniform in each separate outcrop but differ somewhat over the whole region. The color of the fresh unweathered granite is near the color of the enclosing rocks. In the north the granites are purplish and greenish, like the enclosing lavas of the Sarysay formation; in the south, gray or dark-gray, like the graphitic quartzites of the lower part of the Dyusembay formation. These southern granites are characterized by a high quartz content.

Unlike the granite gneisses the granites have well developed protoclastic structure caused by repeated fragmentation and subsequent crystallization of albite, quartz and chlorite.

All varieties of granites have undergone extensive late albitization, as indicated by the development in microcline of large veinlets of replacement perthite oriented ⊥ (1502). In syenites, chemically akin to granites, albitization was even more intensive and produced albitite veins [4]. In the granite gneisses albitization of this type is observed only in the zone

vhere they pass gradually into granite but not .way from it. The granites themselves have nly slightly affected the porphyroids of the Dyusembay formation at the contacts. The ormation of granite gneisses, granites and yenites was a single process, evidently conected with the more intensive tectonic movenents which gave rise to the Maytyuba anticlinorium.

The Structural Position of Granite Gneisses

A study of the microstructures of the granized Lower Proterozoic rocks of the southern Jlutau shows that the processes of recrystallication and feldspathization often differed in ocks very similar in composition but on the ther hand have impressed similar structures n rocks different in composition.

In the peripheral anticline complicated by maller folds (northeast of the area of Figure), the microstructures of the porphyroids were tudied along an east-west traverse at right ngles to the strike (Figure 4). The developnent of crystalloblastic areas in a sequence of orphyroids more or less alike in composition aried in intensity. In the axial parts of the entler anticlinal and synclinal folds (Figure 4 nd 5, a, d) areas with coarsely granular crysalloblastic structure (0.15 - 0.30 mm grains) leveloped in a fine-grained groundmass (0.02 -).04 mm grains). In the porphyroids lying in he limb with a medium dip (Figures 4 and 5, , c) recrystallization was weaker (0.04 - 0.12 nm grains), and it was also relatively weak 0.05 - 0.10 mm grains). In the eastern part f the section, in the tight folds (Figures 4 and , e, f).

It is interesting that the metasomatic changes n the rocks of this section appear only in the xial zones of the folds, as shown by the preence of broad muscovite flakes developed after lagioclase and by partial replacement of plagiolase by metasomatic microcline. The primary potash feldspar developed a faint microcline grid, and small aggregates of introduced microcline with wavy extinction appeared in the groundmass.

With stronger recrystallization the rocks of the steeply dipping limbs remained finer-grained than those of the axial zones of the folds. For this reason the map shows clearly defined horseshoe-shaped outcrops of the relatively less metamorphosed rocks (Figure 1, northern and central folds in the eastern anticlinal zone).

The limbs of the folds contain less intensively recrystallized rocks, such as augen gneisses and various schists. The fine-grained groundmass of these rocks only occasionally contains large porphyroblasts of metasomatic microcline.

A study of the characteristics of distribution of microclines of the first and second type with more or less sharp grid structure shows that potash feldspar with the sharpest grid occurs in the limbs of the folds. This fact is explained by the hypothesis of A.N. Winchell and H. Winchell [1] that pressure favors change of orthoclase, a monoclinic mineral without a grid, into triclinic microcline with a clear grid structure.

A characteristic feature of granite gneisses and granitized rocks is their conformable attitude with the "primary" rocks. The strikes and dips of banding in granite gneisses coincide with the attitude of the primary rocks whose relicts are found among them.

In the western anticlinal zone the western limbs of the anticlines are composed of porphyroids of the Dyusembay formation containing a bed of granular quartzite in the lower part. In the eastern limbs the rocks are strongly granitized and the quartzite bed is only locally preserved. The eastern limbs are composed

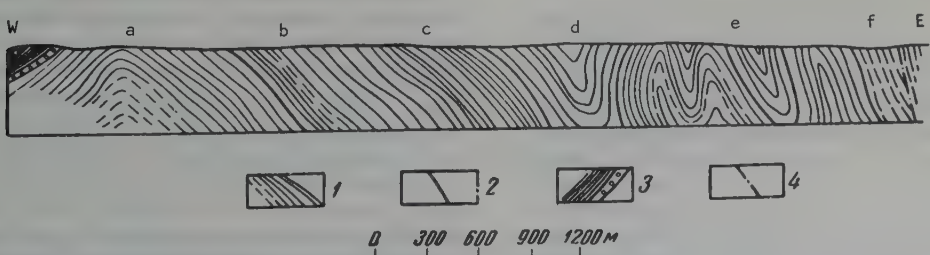

FIGURE 4. Dependence of development of crystalloblasts on the position of the rocks in the folded structure.

1 - porphyroids and quartz-sericite schists; 2 - key horizons of dark-gray porphyroids; 3 - quartzites and quartzitic schists at the base of the Tumurzin formation.

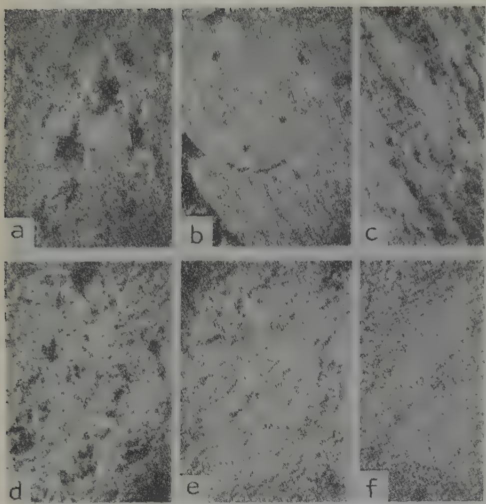

FIGURE 5. Microscopic textures (a - f) of porphyroids. Crossed nicols, x 18.

of granite gneisses in which the folded structure is reflected by the orientation of dark minerals and the attitude of relict gneisses. The dip of banding planes in the gneisses establishes the transition from the anticlinal to the neighboring synclinal fold. The cores of anticlines contain granite. The western anticlinal zone, extensively granitized and bounded by nearly north-south faults, reveals the deepest section through the structure.

To the east lies a large syncline with limbs composed of the rocks of the Tumurzin formation metamorphosed into amphibolites and gneisses. The central part of this large fold is filled with diorite. In its northern closure, among amphibolites there are abundant injections of diorite and thinly banded injection gneisses. The southwestern limb of the fold is cut off by a large fault.

The eastern anticlinal zone includes three anticlines. The largest, the northern fold, is composed of the rocks of the Dyusembay formation. Gneisses are developed in the deepest axial zone of the anticline and in the anticlinal fold complicating its western limb, but the porphyroids in its limbs are only slightly sericitized. In the north this fold is cut off by a large nearly east-west fold. In the core of the next anticline to the south there are granite gneisses formed by granitization of the rocks of the Dyusembay formation. The horseshoe pattern of the gneisses on the map outlines the limbs of the fold. The third fold, composed of sericitized porphyroids, is exposed only in the northern part, being covered in the south by the rocks of the Karsakpay series.

The area of development of granite gneisses and granitized rocks in the eastern anticlinal zone is considerably smaller than in the western, because the eastern zone, together with the adjacent syncline containing diorite, has been lowered in relation to the western.

To the north of these structures lies an anticline formed in the rocks of the Tumurzin formation metamorphosed into leucocratic and mesocratic gneisses. Its core is composed of syenites, and its periphery, of gneisses and granite gneisses. This brachianticline, like the folds of the eastern anticlinal zone, is overturned, so that its western limb has steep reversed dips and the eastern has relatively gentle dips not exceeding 55°.

This fold is bounded by nearly east-west, north-south and northwest faults forming a triangular block. The block is displaced and evidently slightly lowered with respect to the central block and the northeast structure, in which granite gneisses are localized in the cut off part of the anticline adjacent to the fault and shifted with respect to the anticline of the northern block.

Thus, on the whole, granite gneisses and granites are restricted to the Maytyuba anticlinorium. In the central part of the anticlinorium they have very irregular areal distribution and their outcrops are confined to the folded structures eroded to different levels. In the most deeply eroded area, granites are exposed in the cores of the western anticlinal folds. The limbs of these folds are composed of granite gneiss. On the other hand, those folds which have cores of granite gneiss have limbs of granitized rocks. The process of granitization was still less intensive here and primary rocks are easily recognized.

In the southern part of the anticlinorium, where granite gneisses have low dips as measured on the attitude of relict rocks and the orientation of gneissoid structure, paragneisses are poorly preserved, while in the folds with steeply dipping limbs the degree of granitization is considerably less and the rocks of the roof are much better developed (the syenite massif region). Evidently the limbs of the folds subjected to a different set of stresses were less favorable to granitization. Thus, granitization was most intensive in the cores of the folds, less so in the gently dipping limbs, and still less in the steeply dipping compressed limbs. Such definite localization of granitization to the folded structure indicates that it was syntectonic.

The structures of the second order within the anticlinorium, judging by the facies changes in the section of the Tumurzin formation, are

syngenetic with the larger structure. The subsequent development of the minor structures was accompanied by granitization of the Lower Proterozoic sequence, for pebbles of granitized rocks and granite gneisses occur at the base of the Upper Proterozoic. At the same time, the rhyolites of the Sarysay formation in the roof of the granite body were subjected by them to contact metamorphism. Granite pebbles occur only in the Lower Cambrian conglomerates. The gradual transitions between granites and granite gneisses indicate continuity of formation of these rocks during the Lower Proterozoic and the beginning of the Upper Proterozoic.

In the central part of the anticlinorium, granites are localized in anticlines. To the north of it, their position in the structure was predetermined by a fault trending north along the axial part of the northern extension of the anticlinorium. This fault was evidently formed at the Lower-Upper Proterozoic boundary. The participation of faulting in the localization of granites resulted in a widespread development of protoclastic structures in them, while later minor diagonal faulting gave them cataclastic textures.

The governing role of folded structures in the distribution of granites and granite gneisses in our region is not exceptional. N.G. Markova [2] has pointed out that the Proterozoic granite gneisses of the Bet-Pak-Dala region (Central Kazakhstan) occur exclusively in the positive structures of uplifted regions and has shown that individual massifs are related to particular anticlines. The tectonic position of the Archean granites of Eastern Siberia described by N.F. Frolova [6] provides a similar example. Frolova notes that the folds of the third order in the Archean complex are relatively simple in form and have average dips of 40-60°. Most of them are symmetrical folds, but a few are overturned folds with the crests 1 to 5 km apart. The crests of the folds contain alaskites surrounded by granites which, depending on the composition of the enclosing gneisses, are enriched in biotite, hornblende or pyroxene. Along the periphery of these concordant granite massifs there are zones of migmatized gneisses. The process of granitization developing in many centers caused the formation of a large number of concordant alaskite bodies. The granites containing dark minerals, migmatites and various gneisses in the limbs of the folds are, in Frolova's opinion, more or less "undergranitized" rocks.

While in general granite gneisses develop preferentially in anticlines formed on uplifted areas, they develop also in the cores of synclines. An interesting example was described by Eckelmann and Poldervaart [8] from the Beartooth Mountains (Montana and Wyoming) where a large syncline contains granite gneisses in its core while its limbs are composed of biotite hornblende, and microcline biotite migmatites, para-amphibolites, biotite schists and Precambrian quartzites. The limbs of the syncline have dips from 60 to 80°, the granite gneisses merge gradually into the metasedimentary rocks and their banding coincides with the schistosity of these rocks. Thus, the limbs of the fold are composed of various metasedimentary rocks while its core contains granite gneisses.

REFERENCES

1. Winchell, A.N. and H. Winchell, Opticheskaya mineralogiya. [OPTICAL MINERALOGY]: Izd. inostr. lit., 1953.

2. Markova, G.N., O vozraste i polozhenii v strukture intruziy Bet-Pak-Daly. [AGE AND POSITION IN THE STRUCTURE OF THE BET-PAK-DALA INTRUSIVES]: Sov. geol., sb. 51, 1956.

3. Marfunin, A.S., O petrograficheskom znachenii strukturnykh prevrashcheniy v polevykh shpatakh. [PETROGRAPHIC SIGNIFICANCE OF STRUCTURAL TRANSFORMATIONS OF FELDSPARS]: Sov. geol. sb. 51, 1956.

4. Pavlova, T.G., Karsakpayskiy massiv shchelochnykh i nefelinovykh siyenitov i yego polozheniye v tektonicheskoy strukture. [KARSAKPAY MASSIF AND ITS POSITION IN THE GEOLOGIC STRUCTURE]: Izvestiya, Akad. Nauk SSSR, ser. geol., no. 10, 1959.

5. Rezolyutsiya soveshchaniya po unifikatsii stratigraficheskikh skhem dopaleozoya i paleozoya Vostochnogo Kazakhstana (12-17 maya 1958 g. Alma-Ata). [RESOLUTION OF CONFERENCE ON UNIFICATION OF PRE-PALEOZOIC AND PALEOZOIC STRATIGRAPH OF EASTERN KAZAKHSTAN (MAY 12-17, 1958 ALMA-ATA)]: Izd. Akad. Nauk, KazSSR, 1958.

6. Frolova, N.V., O proiskhozhdenii granitov arkheya Vostochnoy Sibiri. [THE ORIGIN OF ARCHEAN GRANITES OF EASTERN SIBERIA]: Izvestiya, Akad. Nauk SSSR, ser. geol., no. 1, 1953.

7. Shtreys, N.A., Osnovnyye cherty stratigrafii dokembriya Tsentral'nogo Kazakhstana. [MAIN FEATURES OF PRECAMBRIAN STRATIGRAPHY OF CENTRAL KAZAKHSTAN]: Tr. Soveshch. po unif. stratigraf. skhem dopaleozoya i paleozoya Severo-Vostochnogo Kazakhstana. Izd. Akad. Nauk KazSSR, 1960.

8. Eckelmann, F. D. and A. Poldervaart, Geologic evolution of the Beartooth Mountains, Montana and Wyoming. Byull. Geol. Soc. Amer., vol. 68, no. 10, 1957.

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GEOTECTONIC POSITION OF RUDNYY ALTAY AND KALBA ACCORDING TO GEOLOGICAL DATA[1]

by

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1. Introduction

The southwestern Altay region occupies the basins of the right-hand tributaries of the Irtysh River (Uba, Ul'ba, Bukhtarma and Kurchum rivers) and the upper courses of the left-hand tributaries of the Ob' River (Aley and Charysh rivers). It trends northwest for approximately 400 km. The northwestern part of this region is known as the Rudnyy Altay, the southeastern, as the South Altay.

Tectonically it is intermediate between the structures of central and northeastern Kazakhstan, on the one hand, and the folded structures of southern Siberia, on the other. This is probably the reason why relatively little attention has been given to the southwestern Altay in the recently published tectonic summaries by P. N. Kropotkin [13], R. A. Borukayev [4, 5], and by Siberian geologists, for example by V. A. Kuznetsov [14]. Lately it was discussed in more detail in a special article by V. P. Nekhoroshev [18] and by P. F. Ivankin [11]. Discussions of the structure of the individual parts of the region and of the adjacent areas based on new data were recently published by M. V. Muratov and V. I. Slavin [17], D. I. Gorzhevskiy [8], D. I. Gorzhevskiy, V. A. Komar and G. F. Yakovlev [9] and Ye. D. Vasilevskaya [7].

In the present paper we attempt to generalize the available geologic and gravimetric data and determine the position of Rudnyy Altay and Kalba among the adjacent structures of Kazakhstan and southern Siberia.

2. The Zaysan Geosynclinal System and Its Boundaries

The southwestern Altay is one of the zones of the Zaysan geosynclinal system, separated by V. P. Nekhoroshev under the name of Zaysan geosyncline. He set the northeastern boundary of the geosyncline at the Salair folded zone, lying in the eastern part of Gornyy Altay. Nekhoroshev believed that in Middle Paleozoic time this zone was an uplifted belt with northeast, locally submeridional trend, separating the Zaysan geosyncline from the West Sayan -- Tuva geosyncline. In the opinion of other investigators [2] the western part of Gornyy Altay lies beyond the boundaries of the Zaysan geosyncline. Most investigators believe that the geosyncline is bounded in the southwest by the Chingiz geanticline, which rose during the Caledonian orogeny and separated the Zaysan geosyncline from the Hercynian Pribalkhash geosyncline. The Chingiz geanticline has a complex structure and consists of a series of anticlines and synclines which trend northwest in the south, nearly due north in the north, and in the region of Pavlodar swing to the northeast and plunge under the Cenozoic cover of the West Siberian lowland. Recent geological and particularly geophysical data indicate that the Variscan Kolyvan'-Tomsk folded zone described by V. A. Kuznetsov evidently lies on the continuation of the folded structures of Eastern Kazakhstan. In the southeast the Zaysan geosyncline extends into the territory of the Chinese People's Republic, where it plunges beneath thick Cenozoic deposits.

Within the indicated boundaries, the Zaysan geosynclinal system contains four structural-facies zones, differing substantially in structure, age of the main epeirogeny and orogeny and in some other features. These zones are: 1) the Gornyy Altay zone (the western part of Gornyy Altay region), 2) the Rudnyy Altay zone, 3) the South Altay zone and 4) the Kalba zone. In our opinion, these zones are the principal geosynclines complicated by large anticlinoria and synclinoria.

3. The Gornyy Altay Tectofacies Zone

The oldest rocks exposed in this zone are schists of supposed Proterozoic age, forming an uplifted tectonic block within a large anticlinorium [2]. Cambrian rocks outcrop only in the easternmost part of the investigated territory on the left bank of the Katun' River. They are composed of Lower and Middle Cambrian limestones,

[1] Geotektonicheskaya pozitsiya Rudnogo Altaya i Kalby po geologo-geofizicheskim dannym.

andesites, sandstones and shales. Stratigraphically above them lie Ordovician rocks represented by a thick sequence (4 – 5 km) of variegated siltstones and sandstones. Silurian rocks are much less widely distributed and are found mainly in the northern part of Gornyy Altay. They are limestones and subordinate siltstones with a thickness of 1. 5 km.

The Lower Devonian deposits are also limited in distribution and are represented by continental sediments with interbedded limestones. The Middle Devonian rocks are much more abundant and include acid, less frequently intermediate volcanics with subordinate limestones and continental deposits. The Upper Devonian rocks are less widely distributed than the Middle Devonian, lie with erosional disconformity on the underlying rocks, and at their base contain fossils of the upper Zhivetian stage. These deposits are mainly of Frasnian and Famennian age and mostly continental. The Devonian rocks of the western part of Gornyy Altay are, in general, very irregularly distributed, evidently due to the existence of isolated downwarps and upwarps. One of the most pronounced of the downwarps is the Anuy-Chuy synclinorium, in which the Devonian strata are 9 to 10 km thick [2].

No marine Lower Carboniferous sediments exist within Gornyy Altay, indicating that intensive uplifts occurred in its western part in pre-Lower Carboniferous time. The later Upper Paleozoic rocks are either absent or are represented by thin continental deposits. The widely distributed intrusives are of different ages and are mainly granitoids related to Caledonian [15] and Hercynian folding. The latter cut through the Upper Devonian deposits and evidently correspond in age to the intrusives of the southwestern Altay.

Thus, during the Lower and the greater part of the Middle Paleozoic era, Gornyy Altay was, in general, undergoing intensive subsidence, succeeded in the beginning of the Carboniferous period by a sharp uplift. Subsequently the geosyncline evolved gradually into a platform. As has already been mentioned, during the Middle Paleozoic (and perhaps even during the Lower Paleozoic) Gornyy Altay was not a single homogeneous structure but consisted of zones of upwarping and downwarping, anticlinoria and synclinoria. Two large anticlinoria formed in it, the Kholzun-Chuy and the Talits, were not covered at all by the Devonian sea. They were bordered by two synclinoria, the Tigerets and the Anuy-Chuy.

During the Devonian a thick sequence of marine sediments accumulated in these synclinoria.

To the southwest of the Gornyy Altay geosyncline lies the southwestern Altay geosyncline containing two structurally distinct regions, the Rudnyy Altay and South Altay.

4. The Rudnyy Altay Tectofacies Zone

The oldest deposits of this zone are quartz-sericite-chlorite and quartz-chlorite-epidote schists, and locally slightly metamorphosed siltstones and sandstones tentatively referred to the Ordovician. They are overlain with a sharp unconformity by the Middle Devonian rocks, represented by albitophyre and rhyolite flows and tuffs and subordinate siltstones, sandstones and limestones. On the eroded surface of the Middle Devonian deposits lie Upper Devonian strata overlain in their turn by Middle Carboniferous rocks (with Zhivetian fossils at the base). The Upper Devonian and Lower Carboniferous rocks are either thick continental sequences (mainly siltstone and sandstones) with subordinate intermediate and basic lavas or volcanic rocks of varied composition but predominantly andesites. In the upper Visean age the territory of Rudnyy Altay was uplifted and after that sedimentary and volcanic rocks accumulated only in the intermont basins. The Upper Paleozoic rocks of Rudnyy Altay are divided into two formations, the lower, Lower Carboniferous, composed of continental rocks alternating with acid effusives, and the upper, Permian, composed mainly of acid and intermediate volcanics and lying unconformably on the underlying formations.

The intrusive rocks of Rudnyy Altay are widespread and belong to at least three complexes of different ages, of which the oldest one is related to the Tel'bess tectonic phase. Characteristic of the region are gabbros and plagiogranites known as the Zmeinogorsk complex. These intrusives cut through the Middle Carboniferous deposits.

During the Middle Paleozoic the territory of Rudnyy Altay contained uplifted and downwarped zones separated by deep faults. Two of these zones correspond to the modern Aley and Sinyushin anticlinoria and the Bystruchin synclinorium lying between them [9]. The main difference in the lithology of the anticlinoria and the synclinoria is that, in the former, Devonian acid volcanic rocks and limestones are predominant, while the latter are filled with continental sediments and subordinate mainly basic and intermediate volcanics.

As a rule the thickness of the deposits in the anticlinoria is a third or half as great as in the synclinoria and contain more local unconformities and hiatuses. The Lower Carboniferous deposits are usually absent, or if present, fill graben in the cores of the structures (Aley anticlinorium) and do not exceed a few hundred meters in thickness. This indicates that in

The principal difference in the geological story of Rudnyy Altay and Gornyy Altay is e to the fact that during the Lower Paleozoic ne the former subsided at a slower rate than e latter. This is proved by the much smaller ickness of ordovician strata in Rudnyy Altay ess than 1000-1500 m) than in the Gornyy tay (4000-5000 m) and by the complete absence Rudnyy Altay of Silurian deposits, which are despread in Gornyy Altay.

However, during Lower Carboniferous time, ien Gornyy Altay was generally uplifted, an tensive subsidence of the synclinoria occurred the Rudnyy Altay and marine conditions persted.

5. South Altay Tectofacies Zone

The South Altay is the southeastern part of e Southwestern Altay region between the arym River in the northwest and the state undary of the USSR in the southeast. Its geogical structure in similar to that of Rudnyy ltay. Most abundant here are the sedimentary-volcanic rocks of Devonian and Lower Carboniferous ages and massive granitoids of the Zmeinogorsk and Kalba intrusive complexes.

The geology of the South Altay is characterized by the following features: 1) the widespread Silurian strata (on the eastern limb of the South Altay synclinorium) overly a thick Ordovician sequence [7], 2) the section contains over 3500 m of Lower Devonian rocks, and 3) the thickness of the Middle and Upper Devonian and Lower Carboniferous strata (12 - 13 km [7]) is considerably greater here than in Rudnyy Altay (7 - 8 km, according to V. A. Komar and I. A. Grechishnikova, 1957).

All this indicates that during the Paleozoic South Altay was subjected to more prolonged and intensive subsidence than Rudnyy Altay.

South Altay is a large synclinorium gradually rising towards the northwest. This rise is observed also in the southeastern part of Rudnyy Altay in the latitude of Zyryanovsk, where anticlinal structures, still very small in area (Figure 1), begin to appear on the extension of the South Altay synclinorium. In the central part, in the latitude of Ust'-Kamenogorsk, their

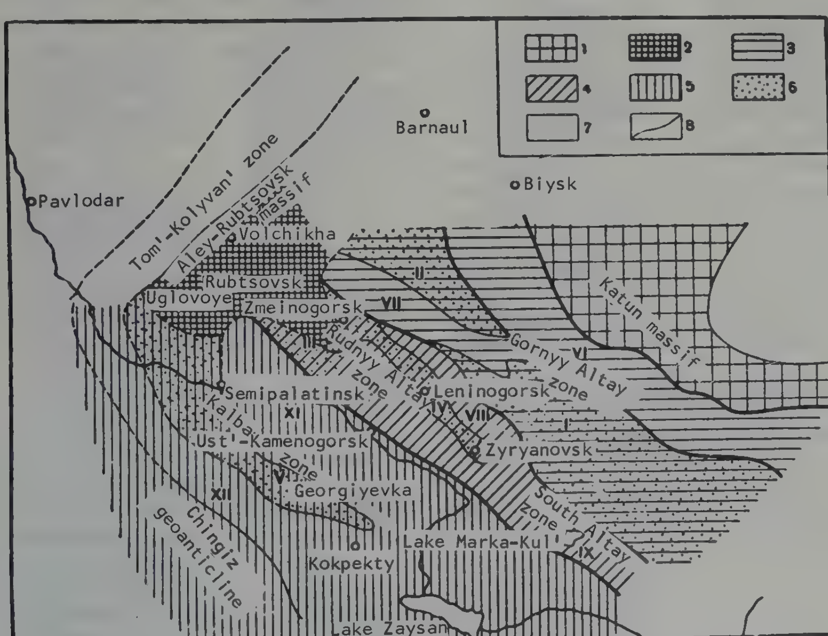

FIGURE 1. Geotectonic regions of Altay and Eastern Kazakhstan

1 - zone of Salair folding; 2 - zone of persistent uplift; 3 - zone of Early Hercynian folding; 4 - zone of Middle Hercynian folding; 5 - zone of Late Hercynian folding; 6 - anticlinoria of the Zaysan geosynclinal system; I - Kholzun-Chuy, II - Talitsk, III - Aley, IV - Sinyushin, V - Charskiy; 7 - synclinoria of the Zaysan geosynclinal system: VI - Anuy-Chuy, VII - Tigerets, VIII - Beloubinsk, IX - South Altay, X - Byztrushinsk, XI - Kalba-Narym, XII - Zharminsk; 8 - deep faults.

area increases rapidly; and still farther to the northwest, in the latitude of Zmeinogorsk, almost all of the region is occupied by the large Aley anticlinorium (Figure 1).

6. The Kalba Tectofacies Zone

To the southwest of the southwestern Altay region lies the post-Hercynian Kalba geosyncline

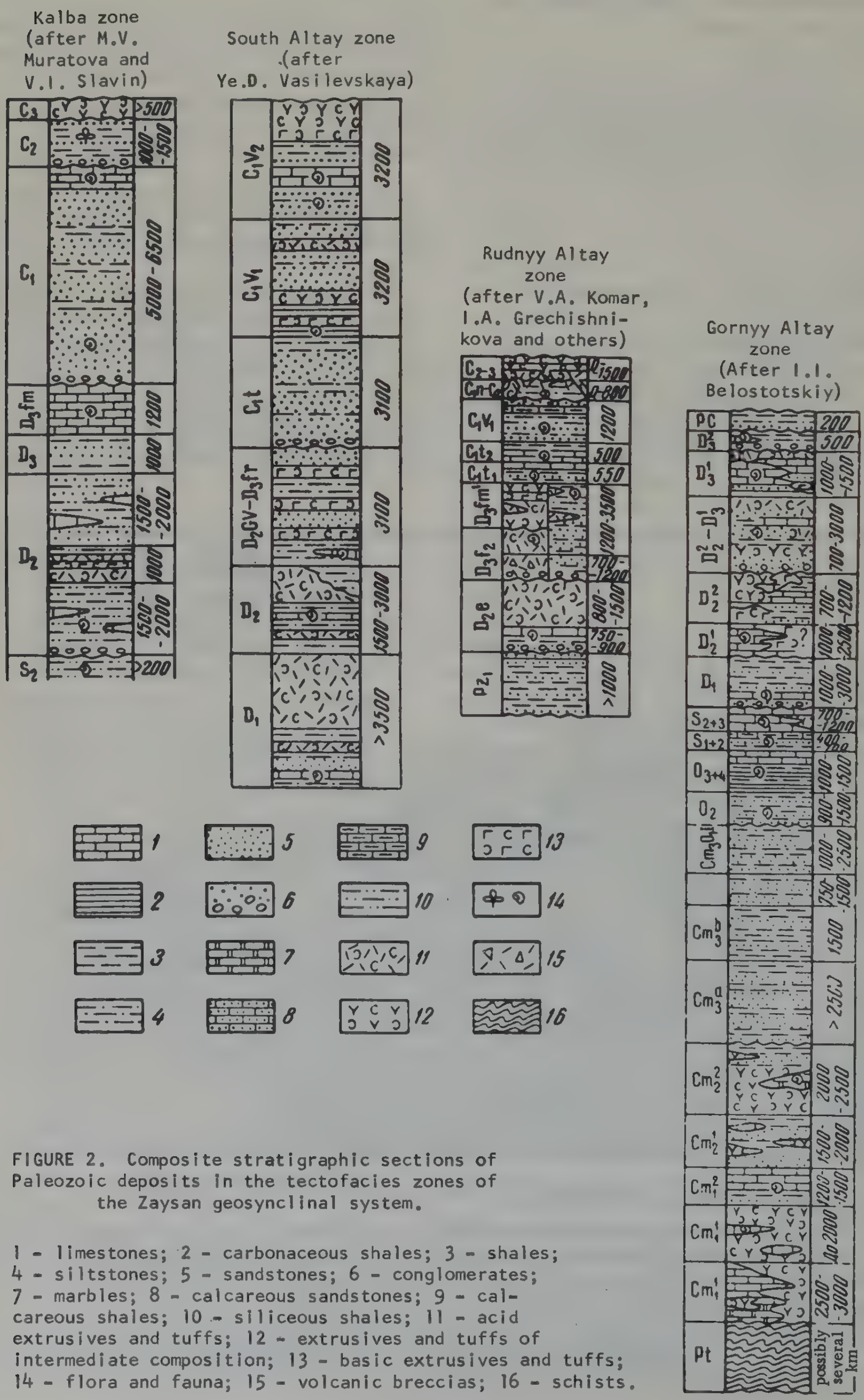

FIGURE 2. Composite stratigraphic sections of Paleozoic deposits in the tectofacies zones of the Zaysan geosynclinal system.

1 - limestones; 2 - carbonaceous shales; 3 - shales; 4 - siltstones; 5 - sandstones; 6 - conglomerates; 7 - marbles; 8 - calcareous sandstones; 9 - calcareous shales; 10 - siliceous shales; 11 - acid extrusives and tuffs; 12 - extrusives and tuffs of intermediate composition; 13 - basic extrusives and tuffs; 14 - flora and fauna; 15 - volcanic breccias; 16 - schists.

t the base of the Paleozoic section are Silurian arbonate rocks and stratigraphically above hem, Middle and Upper Devonian effusive-edimentary deposits 6 to 7 km in thickness. Jnlike the Rudnyy Altay section, this section is redominantly sedimentary. Still higher, the Jpper Devonian sediments are overlain by pre-ominantly continental Lower Carboniferous ocks 5.0 - 6.5 km in thickness. (In Rudnyy ltay the Lower Carboniferous deposits are no nore than 2 - 3 km thick.) At the top of the ection lie thick Upper Paleozoic volcanic-ontinental deposits (Figure 2).

Evidently while Rudnyy Altay was already ndergoing general uplift during the middle 'isean age, which preceded its change into a ubplatform region, the Kalba still maintained geosynclinal regime. The general uplift of he Kalba occurred later, at the end of the Jpper Paleozoic.

Thus, during the Paleozoic era, the region f the Kalba geosyncline was one of very in-ensive and prolonged subsidence. The internal tructure of the region is not homogeneous, and everal structures have been distinguished in it. Vithin its boundaries lies a large anticlinorium Charskiy anticlinorium) composed mainly of evonian rocks [17]. The Charskiy anticlino-ium is bounded on the southwest by the Zhar-ninskiy or Kokpekty synclinorium and on the ortheast by the Kalba-Narym synclinorium. The synclinoria of the Kalba tectofacies zone re filled mainly with Lower Carboniferous and Jpper Paleozoic deposits. They plunge towards he southwest and rise to the northwest.

The intrusives of the Kalba geosyncline are ranitic massifs related to the late Upper aleozoic intrusives of Altay, Kalba and Monastyr. The outcrops of the older intrusive omplexes are seldom encountered.

7. Analysis of Gravimetric Data on the Altay Mountains

A Boguer gravity anomaly map of the South-estern Altay is given in (Figure 3). The com-uted Bouguer anomalies represent the deviations f the average density of the outer layers of the arth from a certain mean value. The differ-nces in density, as is known from geophysical heory, are restricted to the upper sialic layers "granitic" and "basaltic") which lie above the Mohorovicic discontinuity, i.e., within the earth's crust" proper. Beneath the disconti-uity lies a uniform substratum which accord-g to the majority of investigators has ultra-asic composition (V.A. Magnitskiy, Jeffreys nd others).

It is a well known fact that platforms are haracterized by relatively high Bouguer anom-lies, while folded regions have very low nega-tive anomalies. This is clearly shown on the Bouguer gravity anomaly map of the USSR compiled by A.D. Arkhangel'skiy.

These large scale regularities determine the regional background of gravity anomaly depending on the thickness of the crust. The higher the absolute values of the negative Bouguer anomalies, the greater the thickness of the low density layer, i.e., the greater the thickness of the sial [13].

In the Pacific Ocean where, according to Ye. F. Savarenskiy (1949), Gutenberg (1951) and others, the ultrabasic substratum lies directly beneath only a few kilometers of unconsolidated sediments and volcanic material, large positive values of Bouguer anomaly are predominant. Along the north-south section through Central Kazakhstan, according to D.N. Kazanli ([12], Figure 4), the thickness of the sial decreases at least 56 times, from the front ranges of the Tyan'-Shan' to the north. In the northern part of the section, in the region of R.A. Borukayev's "Ordovician trough" and farther north within the Kokchetau crystalline block (pre-Paleozoic plat-form), it is the thinnest. Tentatively the thick-ness of the sial may be regarded here as equal to the total thickness of Archean and Protero-zoic rocks, i.e., to about 10 km.

As in the Central Kazakhstan, the fundamental characteristic of the gravity field of the Altay Mountains is a general increase in the Δg values to the northwest and a decrease to the southeast. The whole area between the towns of Kokchetav, Pavlodar, Semipalatinsk, Rubtsovsk and Novo-sibirsk is characterized by very small Δg values, while in the region of Taldy-Kurgan, Narym Range and the South and Gornyy Altay the Bouguer anomalies decrease. The northern belt of high gravity anomalies between Pavlodar, Semipala-tinsk and Rubtsovsk lies over the continuation of the ancient folded structures of Kropotkin's Kokchetav-Ulutav and Chingiz-Yeremn'tau zones.

In general a graphic representation of the anomalous gravity field, the second order anom-alies being neglected, points to a gradual plunge of the Paleozoic structures to the southeast at a rate which does not vary noticeably in 500 - 600 km, up to the latitude of lakes Zaysan and Marka-Kul'. The highest negative gravity anom-aly lies within the limits of Gornyy Altay and corresponds in general to the Tigerets and Anuy-Chuy synclinoria.

We assume on the basis of these data that the thickness of the sial within the southwestern Altay increases gradually to the southeast. Its minimum thickness is in the region of the Rub-tsovsk anomaly and its maximum in the South and Gornyy Altay.

According to the seismic data published by V.F. Bonchikovskiy [3, p. 131], the thick-ness of the earth's crust along the section

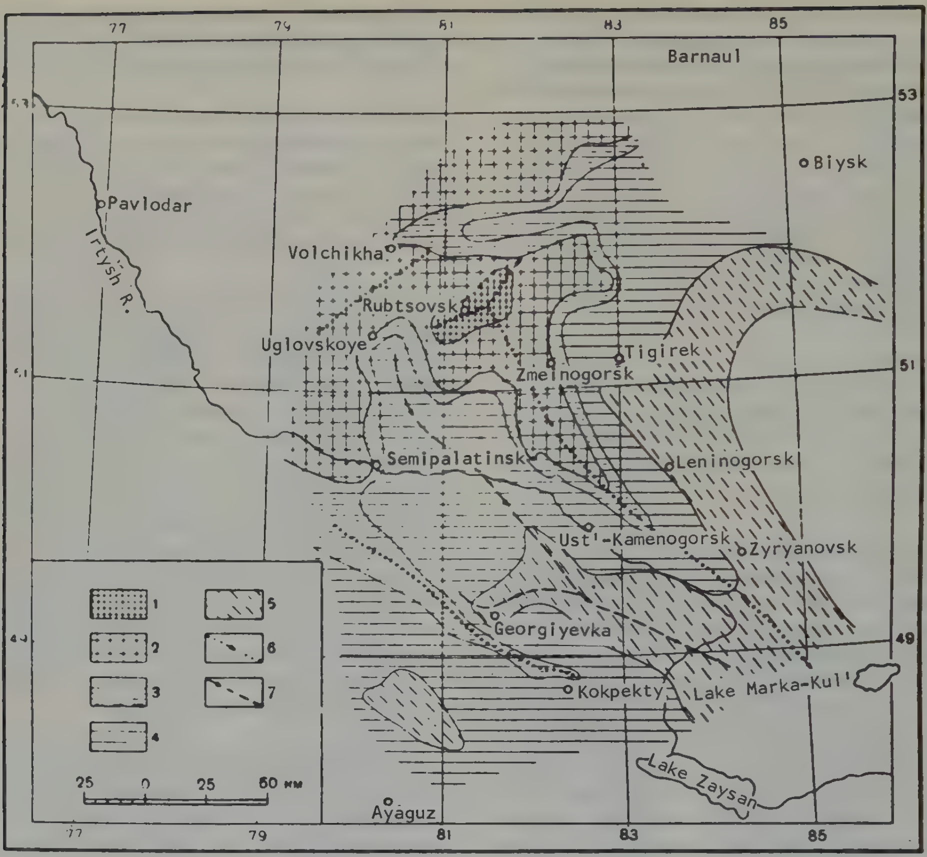

FIGURE 3. Map of gravity anomalies.

1 - areas with very small negative gravity anomalies; 2 - area with small negative gravity anomalies; 3 - areas with average negative gravity anomalies; 4 - areas with large negative gravity anomalies; 5 - areas with very large negative gravity anomalies; 6 - axes of positive gravity anomalies of the second order; 7 - axes of negative gravity anomalies of the second order.

Semipalatinsk-Frunze is 25.8 km with a possible variation of ± 1.9 km. Comparing this information with Kazanli's data cited above on the characteristics of the gravity field in the southwestern Altay, it may be tentatively concluded that the thickness of the crust in the northwestern part of Rudnyy Altay is 20 - 30 km and in the South Altay, 50 - 60 km.

It is very important to note that at least a twofold thickening of the relatively light sialic layer occurs in this case within a single geotectonic unit, the Zaysan geosynclinal system, and contrary to what is observed in Central Kazakhstan is determined by the "Altayan trend" of the Paleozoic structures.

The tectofacies zones of the Zaysan geosynclinal system strike northwest across the trend of the regional gravity field and the supposed change in the thickness of the sial. Each zone has its own local gravity characteristics, anomalies of the second order trending northwest in accordance with the strike of the Altay structures. This complication is the main feature of the southwestern Altay gravity field, and it forms a system of gravitational "rises" and "depressions" trending northwest-southeast and plunging to the southeast (Figure 3).

The zones of the Zharminsk and Kalba-Narym synclinoria are characterized by negative gravity anomalies relatively small in the first and large in the second. The Charsk anticlinorium, and especially the Rudnyy Altay tectofacies zone, on the contrary, stand out as well defined belts of relatively positive anomalies differing considerably from one another, both in the absolute values of Δg and in the rate of change of gravity gradients in transverse sections (Figures 3 and 4).

To the northwest the negative anomalies narrow and wedge out, but the positive ones widen

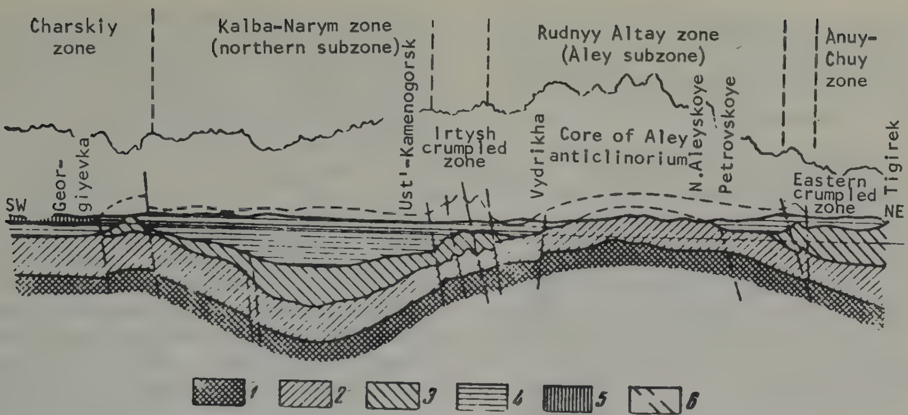

FIGURE 4. Geological-gravimetric section through the southwestern Altay along the traverse: Zhangiz--Tobe--Ust'-Kamenogorsk--Tigerek.

1 - crystalline basement (dense, profoundly metamorphosed Precambrian (?) rocks; 2 - metamorphosed Lower Paleozoic rocks, usually unfossiliferous sandstones and shales; 3 - arenaceous-argillaceous and carbonate Silurian and Lower Devonian rocks; 4 - Middle and Upper Devonian and Lower Carboniferous tuffaceous rocks; 5 - Upper Paleozoic continental and volcanic rocks; 6 - regional faults and crumpled zones (elements of deep faults).

and coalesce into a single broad field of high gravity values which, as has already been pointed out, corresponds areally to the Proterozoic and Caledonian structures extending into Central Kazakhstan.

The general pattern of distribution of the second order anomalies reflects well the alternation of anticlinoria and synclinoria in the tectofacies zone of the Zaysan geosynclinal system to the south of the latitude of Semipalatinsk and Rubtsovsk. In the more northerly parts of the zone, judging by the gravimetric data, the structures were raised and their trend shifted from the southeast-northwest (Altay) to the southwest-northeast direction (Kazanli's "Tekturmas-Selektin" trend) characteristic of some deep-seated structures of Central Kazakhstan and of the entire Kolyvan'-Tomsk folded zone.

At the juncture of these principal structural trends lies the large Aley-Rubtsovsk anomaly. A strong wedge-shaped southeast salient of this anomaly corresponds to the largest folded zone of Rudnyy Altay, the core of the Aley anticlinorium, composed of Ordovician deposits, the oldest in the region.

To determine the probable geological nature of the Rubtsovsk-Aley anomaly, we used what appears to us to be the only reliable method, a comparison of the geological and gravimetric data on the Aley anticlinorium with the data on the adjacent regions where a convincing relation exists between the gravimetric data of similar intensity and the composition and thickness of the structural tiers.

Comparing the data on the Aley anticlinorium and Gornyy Altay, we inevitably come to the conclusion that the anomaly cannot be related to the Ordovician schists exposed in the core of the structure and even less to the granitoids intruded into them. This is confirmed by the fact that a very thick sequence of rocks of the same age and composition in Gornyy Altay gives a negative gravity anomaly. An analogous picture is observed in the Chingiz Range, where the total thickness of Ordovician and Upper Silurian sedimentary and volcanic-sedimentary sequences is about 9 km [8].

On the other hand, the nearest region with gravity anomalies identical with those of the Aley-Rubtsovsk structure is the region of Upper Proterozoic structures such as the Maykain-Ekibastuz and Yeremen'tav anticlinoria. The total thickness of the Upper Proterozoic deposits there exceeds 7 km, and they are underlain by a thick (over 2.5 km) amphibolite formation of the Lower Proterozoic.

On the basis of these facts, the Rubtsovsk-Aley structure may be considered as having been consolidated in the Upper Proterozoic and slightly lowered in the Lower and Middle Paleozoic. The thickness of the Lower Paleozoic formations within the Aley anticlinorium, as has already been noted, is comparatively small, and this is indirectly confirmed by their relatively undisturbed attitude. Thus the Aley-Rubtsovsk structure is evidently an inherited uplift.

The Charskiy anticlinorium is also marked by a high anomaly, but its intensity is considerably lower. The anomalous gravity field has the

form of a narrow ridge more than 200 km in length with its axis close to the western tectonic boundary of the zone with the Zharminskiy synclinorium.

The anomaly narrows and wedges out to the southeast (near the village of Kokpekty). To the northwest it widens, increases in intensity and in the area of Grachevka-Semipalatinsk coalesces with the Aley-Rubtsovsk anomaly. In this particular area, according to geological data, the basement is near the surface. This suggests that the Charskiy anticlinorium, which appeared as a stable uplift within the geosyncline at the end of the Devonian, is similar to the Aley anticlinorium not only in its Middle and Upper Paleozoic tectonic history but also in origin. Both anticlinoria are evidently narrow and long spurs of the large Aley-Rubtsovsk massif, bounded by northwest faults. They are characterized by northeast plunges and increasing thickness of the Middle Paleozoic section in that direction, by an intimate relation to abyssal faults separating these uplifts from the adjacent downwarps, by the predominance of volcanic rocks in the Devonian section and a sharp diminution and complete disappearance of the Lower Carboniferous sediments. The differences in the intensity of the gravity fields are probably due to the differences in the depth to the Precambrian formations and possibly to the difference in their content of basic igneous rocks.

The Kalba-Narym synclinorium is characterized geophysically by a deep gravimetric low with the isogams forming a narrow trough plunging to the southeast. The lowest values of gravity have been found in the southeastern, the Narym part of the zone; the highest, in the latitude of Semipalatinsk, where the Kalba-Narym synclinorium is terminated by a general uplift of the deep-seated geologic structures. It appears that in the southeast, beginning with the latitude of Ust'-Kamenogorsk and the village of Georgiyevka, the base of the Kalba downwarp plunges into the sial to a very considerable depth. This downwarp, as shown by detailed gravimetric profiles across the strike of the geosyncline, is very persistent in all profiles and is accompanied by a rather rapid decrease of gravity gradient as the center of the downwarp is approached from the side of Rudnyy Altay and the Charskiy anticlinorium.

The gravimetric pattern observed in Kalba and Narym cannot be satisfactorily explained by assuming the same relationship between the Middle and Lower Paleozoic rocks as was established for Rudnyy Altay. In other words, the assumption that the Kalba-Narym synclinorium began to form during the Middle Devonian does not fit the large negative gravity anomaly observed in this zone. It is contradicted by a comparison of the thickness of the Middle Paleozoic deposits in the localities where it can be reliably established, with the intensity of gravity anomalies. The maximum known thickness of the Middle Paleozoic deposits, for example, in the region of Bystrushinskiy synclinorium is about 8 km. There is good evidence for stating that this section is underlain, just as on the limbs of the Aley anticlinorium, by Ordovician rocks and that the Silurian and Lower Devonian deposits are absent. Yet this very deep basin is characterized by relatively small, negative Δg values, i. e., by values in general characteristic of the limbs of an anticlinorium. It must be assumed, therefore, that the basement in the Kalba-Narym zone does not consist of dislocated Ordovician deposits but of much older formations, possibly Precambrian, and that thick Lower Paleozoic strata lie in the deeper parts of this zone.

An analogous hypothesis based on other considerations was advanced earlier by Kropotkin, who regarded this zone as an intrageosyncline inherited from the Lower Paleozoic [13].

The belt of low Δg values turns sharply to the east in the latitude of the Narym River, embraces the entire South Altay tectofacies zone, turns to the northwest and then parallels the northeastern crumpled zone. In the latitude of Zmeinogorsk it once again turns sharply to the east and enters the boundaries of Gornyy Altay. Here, in the first approximation, the field of low Δg values corresponds to the Tigiretsk and Anuy-Chuy synclinoria.

On the basis of all this, it is logical to suppose that the belt of low gravity anomalies corresponds to an area of deeply plunging pre-Paleozoic basement and to thick and complete Lower and in part Middle Paleozoic sections. In the South Altay only the Middle Paleozoic rocks are exposed (and in part the Upper Paleozoic) although, as was stated above, in contradistinction to the northwestern parts of the geosyncline, here the Middle Paleozoic section contains Silurian and Lower Devonian rocks. The lower parts of the section are buried under Middle Devonian deposits and cannot be studied directly. We can judge of their composition and thickness only indirectly by using the data on the adjacent zones, the Kholzun-Chuy anticlinorium and the Anuy-Chuy synclinorium.

According to V. P. Nekhoroshev [18], Yu. A. Kuznetsov [16], L. L. Khalfin [20] and V. A. Kuznetsov [14], the Anuy-Chuy zone was for a long time a geosynclinal downwarp which, unlike the more westerly regions, became consolidated in late Caledonian or early Variscan time. The Paleozoic deposits of this synclinorium include four tiers: Cambrian, Ordovician, Silurian and Devonian. In the first approximation, the total thickness of the last three tiers equals the depth to the base of the Cambrian formations and exceeds 15 km. It seems to us that this great thickness of rocks of relatively low density can satisfactorily explain the nature of the Anuy-Chuy gravity low.

A comparison of these data with the gravimetric characteristics of the southern parts of the Zaysan geosynclinal system leads to the conclusion that in the Narym Range and South Altay regions the Carboniferous-Middle Devonian deposits are underlain by very thick arenaceous-argillaceous Lower Devonian, Silurian and Ordovician strata.

In light of these considerations, a quite satisfactory explanation of the Rudnyy Altay gravity anomaly may be proposed. The main peculiarity of this anomaly is its form resembling a cone cut along the axis and laid on a horizontal plane. The base of the cone falls on the Aley-Rubtsovsk massif; and its apex, on the southern part of the Rudnyy Altay zone. In every transverse section the axis of this positive anomaly passes through high Δg points at Rubtsovsk and the villages of Verkh-Uba, Zubovka and Soldatovo. Its edges corresponding to the edges of the cone surface are adjacent to the Irtysh and the northeastern abyssal fault zones and are "cut" by them. Both fault zones (10 - 15 km wide) are characterized by steep gravity gradients. The gradients diminish in different directions: in the Irtysh crumpled zone, they decrease to the southwest; in the northeastern zone, they decrease to the northeast.

The characteristics of the gravity field of Rudnyy Altay indicate that the dense deep-seated masses approach the earth's surface in the northern part of the Rudnyy Altay zone and plunge to a great depth in the south. In each transverse section they rise in the axial part of the zone and plunge rapidly near the Irtysh and the northeastern fault zones. The general picture of spatial distribution of the dense masses in Rudnyy Altay zone reflects the existence of a stable ancient uplift plunging to the southeast and buried under the Lower and Middle Paleozoic deposit throughout the entire length of the zone.

These dense masses, as was shown in connection with the Anuy-Chuy zone, cannot be the Ordovician deposits forming the core of the Aley anticlinorium of Rudnyy Altay. They must be older, strongly metamorphosed rocks enriched in femic components, rocks of the pyroxene schist and amphibolite types.

8. Summary

In the northern part of the Rudnyy Altay zone, the known Ordovician deposits (tier II) are underlain at a rather shallow depth by dense masses comparable to the Precambrian formations of the northern part of Central Kazakhstan. These formations (tier I) form the basement of the entire zone. The section in the Aley subzone lacks tier III (post-Caledonian), represented in the neighboring Gornyy Altay zone by carbonate and continental deposits of great thickness (Figure 4). The deposits of tier IV (Middle Devonian-Lower Carboniferous) are characterized by the relatively small thickness of 2 - 3 km in the region of the Zolotushinskiy mine and of less than 2 km in the Zmeinogorsk region. They had been eroded in the Lower Carboniferous time. The shallow water Upper Paleozoic deposits lie on the older eroded formations.

The distinctive features of the southeastern part of the Rudnyy Altay zone are the greater depth to the ancient basement and the greater thickness of the Middle Paleozoic deposits (more than 8 km in the Bystrushinsk synclinorium and in the Zyryanovsk region) containing not only Devonian but also Lower Carboniferous sedimentary rocks.

In the south Altay tectofacies zone, the basement had subsided to a considerable depth and the geosynclinal section contains all overlying tiers (II, III and IV) with the total thickness of the Middle Paleozoic deposits reaching 16 km [7].

Using the total thicknesses of the Lower and Middle Paleozoic rocks cited above, we obtain the approximate depths to the ancient basement. Under the Rudnyy Altay zone they are: 6 - 8 km in the north and 14 - 16 km in the south, and under the South Altay zone 20 - 25 km.

The shaping of the Rudnyy Altay zone as an individual geotectonic unit with a special course of development during the Paleozoic occurred very early, evidently not later than the Upper Ordovician. From that time on, the Aley-Rubtsovsk massif has been a stable consolidated area separating two subsiding basins of sedimentation. An increased intensity of downwarping in the southeast and the predominance of upwarping in the northwest area with its subplatform regime is one of the principal features of the geotectonic development of the Zaysan geosynclinal system during the Paleozoic. These contrasting vertical movements determined the geanticlinal character of development of the Rudnyy Altay structure-facies zone (especially of its northwestern part) and the geosynclinal character of development of the South Altay zone, which may be regarded as typical geosyncline inherited from the Lower Paleozoic time.

The Rudnyy Altay proper is a spur of the ancient Aley-Rubtsovsk massif. Within its boundaries intensive uplifts and erosion continued from the Upper Ordovician. The Middle Devonian subsidence was relatively insignificant and was, moreover, interrupted by local uplifts, as indicated by the unconformable attitude of the Upper Zhivetian and Frasnian deposits on the Eifelian. Beginning with the Lower Carboniferous, erosion predominated in this structure.

The southeastern part of Rudnyy Altay records a transitional condition. An intensive downwarping began here in the Middle Devonian and continued until the Middle Carboniferous, inclusively, and for this reason Middle Paleozoic deposits in the synclinoria occur as a thick, uninterrupted section.

In light of these concepts, the position of the Irtysh and the northeastern abyssal faults becomes clear: they are located at the base of the Caledonian geanticline exposed at present only in the north (Aley anticlinorium) and buried under folded Middle Paleozoic rocks in the southern part of the zone. As the geanticline narrows to the southeast and subsides to a great depth, the faults come closer to each other on the surface. To the northwest, on the other hand, the faults spread apart and their trends are modified somewhat by the shape of the rigid geanticlinal core. The strike of the northeastern fault changes gradually from northwest to north and northeast, and as should be expected, the Irtysh fault at the latitude of Semipalatinsk deviates in the opposite, westerly direction, guided by the salient of the Aley-Rubtsovsk central massif. To the north, somewhere between Semipalatinsk and Pavlodar, it evidently joins the northeast regional faults which predominate here and bound the central massif in the north.

The faults were very probably formed at the time of the greatest contrast in tectonic movements, i. e., at the end of the Ordovician period or in the beginning of the Silurian. An intensive uplift of the ancient geanticlinal structure of Rudnyy Altay was accompanied at this time by no less intensive subsidence of the neighboring Kalba and Gornyy Altay zones. As a result of differential movement of the narrow areas of the earth's crust, deep fissures were formed around the relatively stable ancient geanticline.

This has been proved by geological methods only in the northwestern Altay, where Rudnyy and Gornyy Altay join together and the rocks of the different tiers are exposed. In the Zmeinogorsk region, Silurian deposits are absent and the eroded Ordovician strata are overlain by the Middle Devonian sedimentary-volcanic rocks. On the other side of the fault, in the Kur'insk region, on the other hand, Silurian deposits are very thick, and higher in the section are overlain by Devonian beds [15].

The Irtysh crumpled zone and the immediately adjacent structure contains Middle Devonian (Nikolayevsk and Sugatovsk mining districts) to Lower and Middle Carboniferous rocks, inclusively. Older rocks are unknown here. There is a great difference in the facies composition of the Devonian-Carboniferous strata on the two sides of this fault, and this suggested to G. D. Azhgirey and P. F. Ivankin [1] that the fault must have formed not later than the Middle Devonian. By analogy with the northeastern fault and on the basis of the indirect geological and geophysical evidence cited above, it is more correct to refer the genesis of the fault to the Upper Ordovician-Silurian time.

After forming during the Caledonian stage at the base of a narrow uplift, the faults continued to exist as mobile seams and to release radial stresses during the following, Middle Paleozoic stage in the development of the region. The previously established contrast in the tectonic movements did not diminish but, on the contrary, due to the formation of abyssal faults, continued to exist and increased. Therefore, during the Middle Paleozoic sedimentation cycle, some of the tectofacies zones (Rudnyy Altay, Charskiy anticlinorium) were uplifted and others (Kalba-Narym, South Altay) strongly depressed. The sharpness of the boundaries resulting from the contrasting movements of these zones are such that some of them may be called ancient "horsts" and others, ancient "graben".

There is no doubt that the reasons for intensive volcanism in some zones and weak in others, for the specific character of the sedimentary formations and, finally, the differences in the character of intrusive magmatism and metallogeny must be considered in relation to the different tendencies in the tectonic development of these zones during the Lower and Middle Paleozoic and to the influence of the abyssal faults separating them.

REFERENCES

1. Azhgirey, G. D. and P. F. Ivankin, Glavnyye voprosy izucheniya geologii Irtyshskoy zony smyatiya. [MAIN PROBLEMS IN THE INVESTIGATION OF THE IRTYSH CRUMPLED ZONE]: Byul. Mosk. ob-va yestestvoisp. prirody. Otd. geol., vyp. 3, 1952.

2. Belostotskiy, I. I., O nekotorykh obshchikh voprosakh geologii Gornogo Altaya. [SOME GENERAL PROBLEMS OF GEOLOGY OF THE GORNYY ALTAY]: Tr. Vses. aerolog. tresta, vyp. 2, 1956.

3. Bonchkovskiy, V. F., Vnutrenneye stroyeniye Zemli. [INTERNAL STRUCTURE OF THE EARTH]: Izd. Akad. Nauk SSSR, 1953.

4. Borukayev, R. A., Razvitiye tektonicheskikh struktur severo-vostoka Tsentral'nogo Kazakhstana. [DEVELOPMENT OF GEOLOGIC STRUCTURES OF THE NORTHEAST OF CENTRAL KAZAKHSTAN]: Izvestiya, Akad. Nauk KazSSR, ser. geol. vyp. 18, no. 134, 1954.

5. Borukayev, R. A., Formatsiya dopaleozoya i nizhnego paleozoya severo-vostoka

Tsentral'nogo Kazakhstana. [PRECAMBRIAN AND LOWER PALEOZOIC STRUCTURE OF THE NORTHEAST OF CENTRAL KAZAKHSTAN]: Izvestiya, Akad. Nauk KazSSR, ser. geol., vyp. 17, no. 124, 1953.

6. Bublichenko, N. L. and L. G. Nikitina, Tarkhanskiy razrez (Yugo-Zapadnyy Altay). [TARKHAN SECTION (SOUTHWEST ALTAY)]: Tr. Altaysk. gorno-metallurg. n.-i in-ta, t. 2, 1955.

7. Vasilevskaya, Ye. D., Geologicheskoye rayonirovaniye yugo-zapadnogo Altaya. [GEOLOGICAL SUBDIVISIONS OF THE SOUTHWEST ALTAY]: Materialy Vses. n.-i. geol. in-ta, nov. ser., vyp. 19, 1956.

8. Gorzhevskiy, D. I., K voprosu o geologicheskoy istorii Rudnogo Altaya v paleozoye. [ON GEOLOGICAL HISTORY OF RUDNYY ALTAY DURING THE PALEOZOIC]: Doklady, Akad. Nauk SSSR, t. 101, no. 4, 1955.

9. Gorzhevskiy, D. I., V. A. Komar and G. F. Yakovlev, Strukturno-fatsial'nyye zony Rudnogo Altaya. [STRUCTURAL - FACIES ZONES OF RUDNYY ALTAY]: Sov. geologiya, sb. 48, 1955.

10. Ivankin, P. F., Voprosy geologicheskogo razvitiya Priirtyshskogo rudnogo rayona Altaya. [PROBLEMS OF GEOLOGICAL DEVELOPMENT OF THE IRTYSH MINERALIZED REGION OF THE ALTAY MOUNTAINS]: Tr. Altaysk. gorno-metallurg. in-ta, t. 3, 1956.

11. Ivankin, P. F., Polozheniye Rudnogo Altaya v skheme tektonicheskogo rayonirovaniya Yugo-Zapadnogo Altaya. [THE POSITION OF RUDNYY ALTAY IN THE TECTONIC SUBDIVISION OF THE SOUTHWESTERN ALTAY]: Tr. Altaysk. gorno-metallurg. in-ta, t. 7, 1957.

12. Kazanli, D. N., Struktura Tsentral'nogo Kazakhstana na osnovanii analiza gravimetricheskogo i magnitnogo poley. [STRUCTURE OF CENTRAL ALTAY ON THE BASIS OF ANALYSIS OF GRAVIMETRIC AND MAGNETIC FIELDS]: Izvestiya, Akad. Nauk KazSSR, ser. geol., vyp. 20, 1955.

13. Kropotkin, P. N., Stroyeniye skladchatogo fundamenta Tsentral'nogo Kazakhstana. [STRUCTURE OF THE FOLDED BASEMENT OF CENTRAL KAZAKHSTAN]: Tr. In-ta geol. nauk Akad. Nauk SSSR, vyp. 108, 1950.

14. Kuznetsov, V. A., Geotektonicheskoye rayonirovaniye Altaye-Sayanskoy skladchatoy oblasti. [GEOTECTONIC SUBDIVISIONS OF THE ALTAY-SAYAN REGION]: In the book: Voprosy geologii Azii, t. 1, 1954.

15. Kuznetsov, V. A., Osnovnyye etapy razvitiya magmatizma i elementy metallogenii Gornogo Altaya. [MAIN STAGES OF MAGMATISM AND OUTLINE OF METALLOGENY IN GORNYY ALTAY]: Izvestiya Vost. fil. Akad. Nauk SSSR, no. 2, 1957.

16. Kuznetsov, Yu. A., Materialy k stratigrafii i tektonike Severo-Zapadnogo Altaya. [MATERIALS ON STRATIGRAPHY AND TECTONICS OF THE NORTHWESTERN ALTAY]: Izvestiya Tomsk. politekhnich. in-ta, t. 65, vyp. 2, 1950.

17. Muratov, M. V. and V. I. Slavin, Kratkiy geologicheskiy ocherk Kalby. V kn. Ocherki po geologii Sibiri. [BRIEF GEOLOGICAL DESCRIPTION OF KALBA. IN THE BOOK: ESSAYS ON GEOLOGY OF SIBERIA]: vyp. 16, 1953.

18. Nekhoroshev, V. P., Osobennosti geologicheskogo stroyeniya Altaya i yego yugo-zapadnoy periferii. V sb. Voprosy geologii Azii. [CHARACTERISTICS OF THE GEOLOGICAL STRUCTURE OF ALTAY AND OF ITS SOUTHWESTERN PERIPHERY. IN THE BOOK: PROBLEMS OF GEOLOGY OF ASIA]: t. 1, 1954.

19. Peyve, A. V., Tipy i razvitiye paleozoyskikh struktur Uralo-Tyan'shanskoy geosinklinal'noy oblasti. [TYPES AND DEVELOPMENT OF PALEOZOIC STRUCTURES OF THE URALO-TYAN'-SHAN' GEOSYNCLINAL REGION]: Izvestiya, Akad. Nauk SSSR, ser. geol., no. 6, 1948.

20. Khalfin, L. L., Fauna i stratigrafiya devonskikh otlozheniy Gornogo Altaya. [FAUNA AND STRATIGRAPHY OF THE DEVONIAN DEPOSITS OF GORNYY ALTAY]: Izv. Tomsk. politekhnich. in-ta, t. 65, vyp. 1, 1948.

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STRUCTURAL CHARACTERISTICS AND ORIGIN OF FAULTS IN NORTHERN KARAMAZAR[1]

by

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Northern Karamazar lies on the northern slopes of the Kuraminskiy Range, one of the southwestern spurs of the northern Tyan'-Shan' Mountains and according to V.A. Nikolayev's map (1952) forms a part of the Kuraminskiy structural-facies zone, regarded as the peripheral zone of a late phase in the development of the Variscan geosyncline.

Northern Karamazar is characterized by a wide distribution of the ancient Caledonian basement rocks, i.e. Silurian schists and the Caledonian granitoids intruded into them. These rocks are overlain by relatively thin Paleozoic formations, Upper Devonian-Lower Carboniferous limestones and Middle and Upper Carboniferous volcanics, which are stratigraphically equivalent to the formations separated by N.P. Vasil'kovskiy [1] in the Kuraminskiy zone: the Lower or Middle Carboniferous Mynbulak pyroclastic formation and the Upper Carboniferous Akchin, Sarysiyun and Oyasay formations. The younger volcanic rocks (Permian-Lower Triassic?) present elsewhere in the Kuraminskiy structural-facies zone are absent from the Northern Karamazar area.

The basement rocks and the overlying strata are cut by numerous intrusives and dikes of different ages. The larger massifs are composed of rocks belonging to the first (Middle Carboniferous) intrusive Variscan complex, the so-called Karamazar granodiorites and the Almalyk syenite-diorites, and are accompanied by dike complexes. A smaller area is occupied by the so-called Gushsay granodiorite porphyries. The age of these rocks has not been definitely established; it is known only that they cut through the volcanics of the Upper Carboniferous Sarysiyun formation and are intruded in their turn by the Upper Permian igneous rocks.

Permian, possibly Lower Triassic dikes are widespread in the region.

In the Karamazar region, folded structures are characteristic only of the early Variscan (pre-Upper Carboniferous) orogenic epoch.

The large later intrusions and the products of volcanic activity have greatly stiffened the Northern Karamazar region, increasing the role of faulting and diminishing the role of folding in it. As a result the region has been dislocated by faults into a series of blocks of different sizes which have undergone complex displacement.

Geological investigations have shown that the faults of Northern Karamazar differ in age, history of development and orientation (Figure 1) and may be placed in three groups:

1) faults striking east-west or nearly so (Bashtavak, Burgandin and North Karatag faults);

2) faults striking northeast (50-55°NE) (Zheleznyy and Miskansk faults); and

3) faults striking north-northeast (Chalatinsk, Altyn-Topkan and Tsentral'nyy faults).

Only the best developed fault from each group, one most clearly illustrating the differences in the history of formation of the faults, will be discussed here.

I. The Bashtavak fault represents the first group of faults. It strikes nearly east-west, extends for about 100 km and preserves throughout this distance a steep, locally almost vertical dip to the north. Its ends are concealed by the young Mesozoic deposits of the Fergana valley in the east and of the Murzarabat depression on the west.

The Bashtavak fault is a tectonic zone formed by a series of closely spaced parallel faults. The zone contains dikes and extrusive rocks of different ages (Figure 2).

In the central part, where the fault forms a bend convex to the south, lies a belt of dikes.

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[1]Osobennosti stroyeniya i formirovaniya razryvnykh narusheniy severnogo Karamazara.

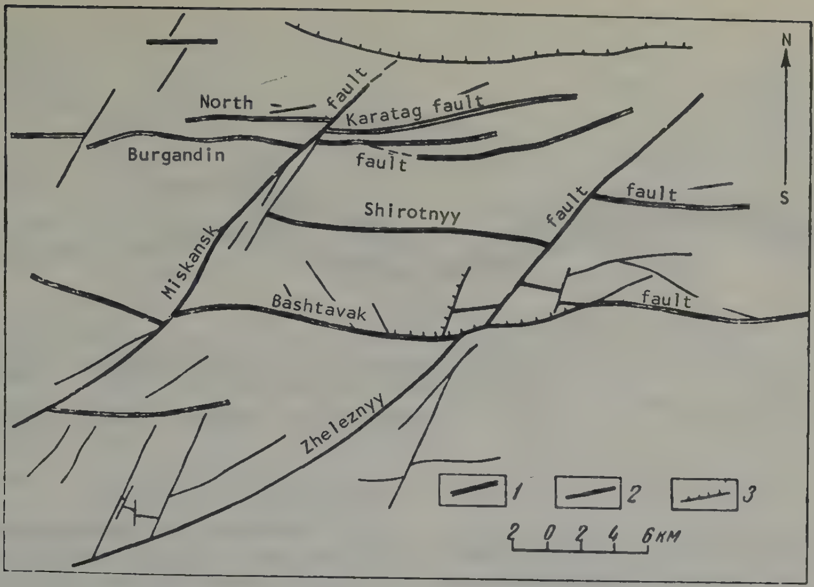

FIGURE 1. Tectonic diagram of Northern Karamazar.

1 - Middle Carboniferous faults; 2 - Upper Permian faults; 3 - Alpine faults.

The fault cuts through the dikes of the first Variscan intrusive complex related to the granodiorites of the so-called Karamazar type. The width of the belt is about 0.7 km and its length, 6 km. A little to the west the Bashtavak tectonic zone contains a granodiorite porphyry stock also of the first (Middle Carboniferous) intrusive complex. Occasional dikes of the same age are found in other areas of the fault zone. From this it may be concluded that at the time of emplacement of these minor intrusives the Bashtavak belt was already a zone of weakness.

During the Upper Carboniferous the Bashtavak belt continued to be a zone of weakness and served as an outlet for extrusive igneous activity. This is indicated by the presence along it of volcanic plugs and feeder dikes responsible for the deposition of the Akchinsk and Oyasaysk volcanic formations. In the central part of the fault, vents filled with dacite lava and tuff breccias are preserved. To the west they are succeeded by horizontal flows of the Akchinsk formation (Figure 2). Dike-like bodies of dacite tuff breccia with abundant xenoliths of Silurian shales have been found at the west end of the fault zone.

Volcanic plugs of the younger Oyasay formation are also found in a number of places along the fault zone. They are usually composed of amygdaloidal andesite, surrounded by acid lava breccia and are 0.5 - 1 km in diameter.

Along the Bashtavak fault zone there are also younger intrusives (Permian) such as the granodiorite porphyries of the so-called Gushsay type and the Shaydan alaskites. These rocks form dikes up to 15 km in length and small stocks. The latter are usually located at the junction between feather joints and the main fault. The dikes of the fourth and youngest intrusive complex are also present in the fault zone. The presence of these rocks suggests that the fault continued to form during the Permian. That the movements along the Bashtavak fault were renewed just before and continued through the stage of hydrothermal activity is indicated by the brecciation of the hydrothermally altered rocks in the fault zone.

Belts of such rocks are traceable along the entire length of the fault and reach a thickness of 150-200 m. Locally they are accompanied by quartz veins.

During Alpine orogeny stresses were again released by the Bashtavak fault and this caused intensive brecciation of the altered rocks and quartz veins. The displacements along the fault brought Paleogene deposits in contact with Paleozoic formations.

This brief description of the structure of the Bashtavak fault zone shows that it developed over a long period of time, from the Middle Carboniferous to the Tertiary.

The author's investigations have shown that

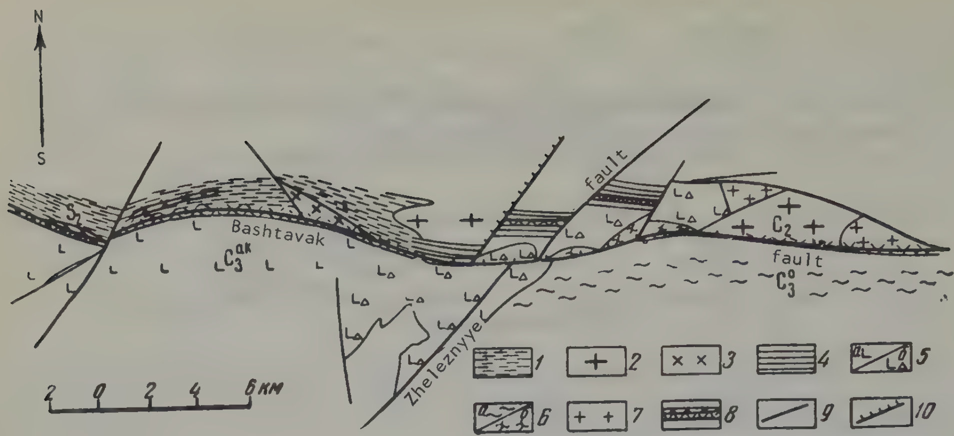

FIGURE 2. Tectonic diagram of the Bashtavak fault zone. Map.

1 - Upper Silurian schists; 2 - Middle Carboniferous granodiorites; 3 - granodiorite porphyries related to granodiorites; 4 - Middle Carboniferous dike belt; 5 - effusives of the Akchinsk formation (Upper Carboniferous): a - flows; b - vents; 6 - effusives of the Oyasak formation: a - flows, b - vents; 7 - Permian granites; 8 - ancient Middle Carboiferous faults; 9 - Permian tectonic dislocations; 10 - tectonic dislocations formed or rejuvenated during Alpine orogeny.

the other large east-west faults of the Northern Karamazar region have also had a similar history. These are the Burgandin and the North Karatag faults.

The long development of the Bashtavak fault zone was accompanied by displacement of opposite blocks. Repeated healing of the fault zone by igneous rocks of different ages makes it difficult to determine the character of these movements, and the masking of the older displacements by the Alpine movements adds to the difficulty. For this reason the character of the displacements has been differently interpreted by different investigators (A.V. Korolev in 1939, A.P. Nedzvetskiy in 1946 and others). Moreover, all attempts to determine the magnitude of the displacements have been reduced to the determination of their visible result. Inasmuch as the present investigation revealed the very long history of the fault, an attempt was made to analyze the character of displacements on the Bashtavak fault at different times.

It is difficult to judge of the displacements of the early period antedating the intrusion of the Middle Carboniferous age. It is possible that the fault zone at that time was represented merely by a zone of weakness which permitted the emplacement of the minor intrusives.

The position of the Akchinsk volcanics (Upper Carboniferous) on the formations of different ages on the two sides of the fault indicates that displacements had occurred before the eruption of these rocks.

At the western end of the fault, the Akchinsk volcanics lie on the Middle Carboniferous volcanics to the south of the fault and on Silurian deposits to the north of it. This suggests that the displacements along the Bashtavak fault before the eruption of the Akchinsk volcanics caused an upward movement of the northern block with respect to the southern and its subsequent erosion. Considering the thickness of the eroded Middle Carboniferous and a part of the Lower Carboniferous formations, it may be assumed that the vertical displacement was approximately 1 km (Figure 3 - I).

After the deposition of the Akchinsk volcanics, but before the formation of the hydrothermally altered zone and quartz veins, movements were renewed along the Bashtavak fault. They are indicated beyond the boundaries of the Northern Karamazar region by the position of the Sarysiyun formation on the two sides of the fault. In 1955 V.N. Levin showed that at this time the northern block was raised 600-700 m with respect to the southern.

An analysis of the position of numerous northwest striking feather joints which became zones of hydrothermal alteration and quartz vein deposition indicates that the movements on the Bashtavak fault were not simple thrusts but had a horizontal component (Figure 3, II).

The character of the Alpine displacements

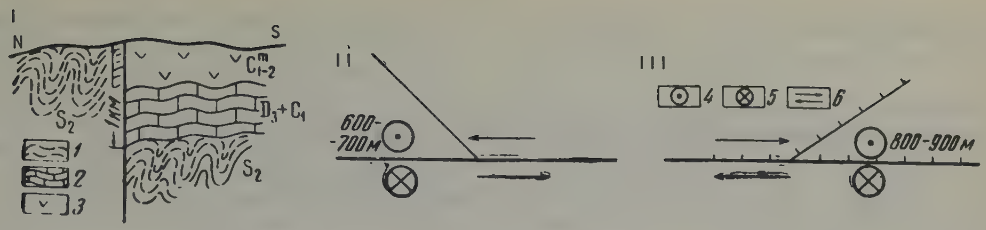

FIGURE 3. Displacements along the Bashtavak fault.

I - before eruption of the Akchinsk effusives of Upper Carboniferous age; II - before hydrothermal activity; III - in Alpine time. 1 - schists; 2 - limestones; 3 - porphyrites of the Mynbulak formation; 4 - uplifted block and the amount of vertical displacement; 5 - lowered block; 6 - direction of horizontal movement.

may be determined from the position of the Paleogene deposits. Paleogene limestones are preserved only to the south of the Bashtavak fault, while to the north of it there are only definitely pre-Paleogene peneplaned surfaces. By comparing the elevations of these surfaces with the surfaces covered by Paleogene sediments to the south of the fault, it is not difficult to show that in the Alpine time the northern block was raised with respect to the southern. The vertical displacement amounted to 800-900 m. The presence of the northeast feather joints at the Bashtavak fault formed during the Alpine orogeny suggests that the movements on the fault were thrusts with a horizontal component (Figure 3-III) and as a result the northern block was not only raised with respect to the southern but also shifted to the east.

Thus, the displacements on the Bashtavak fault were complex but reverse faulting was predominant. Such displacements characterize also the other faults of this group.

II. The Zheleznyy fault belongs to the second group of dislocations. In size it does not yield to the Bashtavak fault (its length is 120 km), but the history of its development is quite different.

The Zheleznyy fault throughout its length preserves a northeast strike (50-55°) and a steep dip of 80-85° to the north. It cuts various rocks from the Upper Devonian-Lower Carboniferous limestones to the Gushsay granodiorite porphyries.

Outwardly the fault appears to be rather uniform; it is a zone of intensively brecciated, crumpled and hydrothermally altered rocks. At intervals through its length there are granite porphyry, quartz porphyry, felsite porphyry, microgranophyre, and diabase dikes. They are the youngest intrusives of the region, belonging to the fourth (Upper Permian-Lower Triassic) intrusive complex. The dikes located in the fault zone are quite long and thick (up to 25 m). Besides the isolated dikes there are dike swarms.

The distinguishing feature of the Zheleznyy fault, therefore, is the absence throughout its length of the older intrusive and volcanic rocks and the presence of young dikes. This indicates that the fault was formed as late as the Upper Permian, i.e. before the intrusion of the dikes of the fourth complex. The final shaping of the fault, however, occurred later, at a time preceding hydrothermal activity. This is confirmed by the presence of thick zones of hydrothermal alteration and of quartz veins throughout the length of the fault. Unlike the Bashtavak fault, the Zheleznyy fault was not reactivated during the Alpine orogeny.

Similar structure and history of formation characterize a number of other northeast

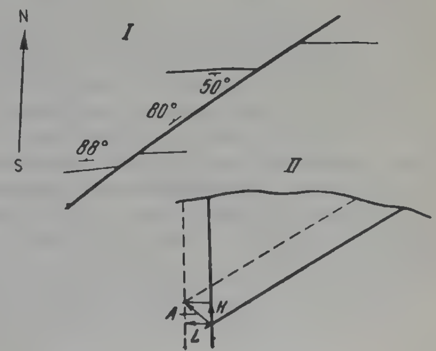

FIGURE 4. Displacements on the Zheleznyy fault.

I - plan; II - section in the fault plane. Fault plane dips 80°. A - total displacement and direction of movement; H - vertical displacement; L - horizontal displacement.

striking dislocations, such as the Miskansk, Aktash and Kaskansay faults.

The nature of displacements on the Zheleznyy fault and their magnitude were measured in 1954 in the southwestern block only by B. N. Nasledov [2], P. A. Shekhtman and Yu. S. Shikhin and by other investigators. Here the visible horizontal slip, judging by the contact of the Upper Devonian-Lower Carboniferous limestones with the Upper Paleozoic volcanics, is almost 4 km.

Within the Northern Karamazar region the Zheleznyy fault cuts a steeply dipping belt of east-west trending dikes located in the Bastavak fault zone and shifts it so that the eastern block is displaced 1.8 km to the north with respect to the western. Twelve kilometers from this locality the Zheleznyy fault cuts and displaces a fault containing dikes and a quartz vein also striking east-west but dipping 50-55° south. As the result of displacement a part of this fault in the eastern block is shifted 4 km to the south (Figure 4, I). The apparent discrepancy in the amount of displacement is explained by the fact that the movements on the Zheleznyy fault were not horizontal but involved thrusting as well. It was determined graphically that the horizontal displacement amounted to 1.8 km and the vertical to 1.5 km (Figure 4, II).

Similar movements occurred on the other faults of this group.

III. The third group of dislocations includes north-northeast striking faults differing from the faults of the preceding groups by their smaller size. As a rule they are developed near the large northeast faults. Some of them are adjacent to the Zheleznyy and Miskansk faults, and our investigation shows that they are nearly contemporaneous with the northeast faults. Some of them contain dikes of the fourth intrusive complex (Upper Permian), but most frequently they appear as zones of hydrothermal alteration with quartz, quartz-carbonate and quartz-barite fluorite veins. In localities where they cut the Upper Devonian-Lower Carboniferous limestones, they contain polymetallic mineralization. The time of their formation and their location suggest that they own their origin to the displacements on the Zheleznyy and Miskansk faults.

The factual material presented in this paper shows that the tectonic dislocations in Northern Karamazar were formed at different times during the geological development of the region. The oldest faults are those with the nearly east-west strikes, the Bashtavak, Burgandinsk and North-Karatag faults. Using the Bashtavak fault as an illustration, it is shown that the faults of this group are characterized by great depth and a long history (Middle Carboniferous to the present).

The northeast striking faults, Zheleznyy, Miskansk and others, are younger. They were formed before or during the period of hydrothermal activity, and the displacements on them produced north-northeast dislocations which became loci of ore deposition.

REFERENCES

1. Vasil'kovskiy, N. P. Stratigrafiya i vulkanizm verkhnego paleozoya yugo-zapadnykh otrogov Severnogo Tyan'-Shanya [UPPER PALEOZOIC STRATIGRAPHY AND VULCANISM OF THE SOUTHWESTERN RANGES OF NORTHERN TYAN'-SHAN']: Izd. Akad. Nauk UzSSR, 1952.

2. Nasledov, B. N., Karamazar [KARAMAZAR]: Tadzh.-Pamir exped., 1933. 1935.

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SOLUTION STRUCTURES IN SEDIMENTARY AND PYROCLASTIC ROCKS[1,2]

by

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A study of pre-Ordovician sandstones and pebble conglomerates of the Mogilev formation in the southwest of the Russian platform in an area where they are deeply buried (Mirnoye and Kaushany boreholes) showed a widespread occurrence of epigenetic solution of detrital quartz and feldspar grains caused by pressure exerted by the overlying strata.

Pressure solution is manifested in these rocks by the formation of a number of characteristic structures not found in the usual sedimentary rocks. The following structures can be distinguished at the contacts between the detrital grains: microstylolitic, characterized by mutual interpenetration of the grains along complex sutured contacts; conformal, in which the contact surfaces are smooth, each grain modifying its original shape to accommodate the shapes of adjacent grains; and the imbedded structure, in which one of the grains retains to a greater or less degree its initial form and partially penetrates another grain, whose outlines are changed to correspond to the intruded part [1, 2].

Further investigations have shown that these structures are widespread. They were observed in the rocks from various regions of the Dnepr-Don basin, in the Upper Paleozoic arkosic and polymict sandstones of the Shebelinsk natural gas field (at the depth of 1600-2300 m), in the Upper Devonian arkosic and feldspathic sandstones penetrated by many boreholes in the Mikhaylovsk, Zachepilovsk, Petrishchevsk and Kolaydinsk reconnaisance areas (at 1500-2600 m) and also in the deeply buried Upper Devonian sandstones and siltstones of the Archedinsk mining district, in different parts of Vtoroy Baku, in Riphaean sandstones of the Orsha and Pinsk formations of Byelorussia, in the Valday, Redkino and older complexes of the central part of the Russian platform, in the oldest continental deposits of Ukhta, of the Sredniy and Rybachiy peninsulas, and in a number of other localities.

M. T. Heald [5], J. M. Taylor [8] and W. D. Lowry [6] have described similar structures from the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Jurassic and Cretaceous sandstones of different parts of the U. S. A.

Ch. M. Gilbert [4] has pointed out the widespread occurrence of mycrostylolitic structures in arkosic sandstones of the middle and upper Miocene of California, penetrated by boreholes at the depth of 2500-3400 m.

These examples show that there is no simple, strict relationship between the development of microstylolitic, conformal and incorporation structures and the age of the rocks. Although these structures are most frequently found in ancient, especially Riphaean formations, they occur on platforms in the deeply buried Paleozoic and Mesozoic deposits in folded regions and in even younger rocks.

The basic factors determining the development of the microstylolitic, conformal and imbedded structures are the depth and duration of burial. Important also are the composition of the grains, their size, the degree of rounding and sorting, the presence and amount of cement, and the composition, regime and temperature of ground water [2].

As shown by microscopic investigations, pure quartz and feldspathic sandstones and arkoses usually exhibit microstylolitic and conformal structure, while the imbedded relationship among the grains is uncommon. The character and form of contact between the grains in these structures indicate identical or nearly identical solubility of the quartz and feldspar grains and

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[1]O strukturakh rastvoreniya v nekotorykh osadochnykh i effuzivno-osadochnykh porodakh.

[2]The author's concepts of widespread development of solution structures in rocks (due to pressure) and his use of these concepts to explain the frequent occurrence of complex morphological relationships between detrital grains must be documented not only by visual observations but also by a discussion of the reactions occurring between the grains. Editors.

the somewhat inferior stability of the plagioclase which leads to the mutual interpenetration of the grains, sometimes forming a microstylolitic seam, sometimes a simple conformal contact. This is not contradicted by the occasional occurrence of imbedded structures with potash feldspar penetrating quartz or quartz penetrating the feldspar.

Simultaneously with the solution of some of the detrital quartz and feldspar grains in these rocks, other grains undergo the reverse process of growth by deposition of regeneration rims extending into available pore spaces, and secondary minerals make their appearance. The simultaneous or nearly so solution and secondary growth of the same minerals indicate that the systems arising in the rock are in a state approaching equilibrium. These systems are affected by various factors, by the surface energy of the detrital components (solution of small grains and growth of the larger ones), by the variation in solubility depending on the magnitude of stress acting upon the grain (increased solubility at contact points) and also by the characteristics of the fine structure of the lattices of the detrital crystals (presence of mechanical admixtures, dispersed inclusions, solid solutions, diadochic admixtures, plastic and mechanical deformation, dislocations in the crystal lattices, etc.).

It follows from what has been said that under confining pressure the most soluble components of sandstones must be those which possess high surface energy and hence low stability, i.e., grains of opal and chalcedony, fragments of siliceous and pelitic sedimentary rocks, fine-grained limestones, marlstones, microcrystalline silicate rocks, or the groundmass of volcanic rocks and glasses.

Thus, a theoretical examination of the solubility of detrital components of sandstones under pressure makes it very probable that conformal and imbedded structures must develop much more abundantly in polymict and tuffaceous sandstones, graywackes and especially in tuffs, tuffites and other pyroclastic deposits rather than in the arenaceous rocks of monomineralic, oligomict and arkosic composition. Moreover, solution structures in these rocks must form under a considerably smaller load and therefore at shallower depth. In folded regions where the load pressure is replaced by stress, the formation of these structures must be expected even in slightly deformed strata.

Microscopical investigation fully confirms these hypotheses. For example, in some quartzose sandstones layers from the Laminarites-bearing beds of the Redkinskiy section containing siliceous lithic fragments, a sharp difference is observed in the degree of solubility of these components. The preferential solution of chert fragments results in the formation of conformal structures in which quartz grains are sharply idioclastomorphic[3] and of typical imbedding of quartz grains in the chert grains accompanied by the regeneration of the former. A similar phenomenon was observed by American investigators in the Lower Cretaceous Cut Bank and Sunburst sandstones of Montana (Kootenai formation). In these rocks, composed of quartz and chert grains, L. L. Sloss and D. E. Feray observed widely developed microstylolite seams between grains of like composition, but such seams were absent in quartz-chert contacts. Here chert grains are dissolved and quartz is imbedded in them. The dissolved silica regenerates quartz grains only but not the chert grains [7].

Pressure solution structures are common in the Carboniferous sandstones of the Dnepr-Don basin (Shebelinka) lying at a considerable depth (2919-2925 m). These are typical polymict rocks composed of quartz, potash feldspar (mainly microcline), plagioclase, biotite flakes and fragments of chert, quartzites of different textures, phyllite, argillites, mica, quartz-mica and muscovite-quartz schists, acid, intermediate and basic volcanic rocks and volcanic glasses. In rare cases there is recrystallized primary cement represented by a mineral of the kaolinite group. The structure of the sandstones is largely due to the development of conformal, imbedded and, infrequently, microstylolitic contacts and to plastic deformation producing continuous aggregates of detrital grains. The regeneration and enlargement of quartz grains and the development of secondary minerals also contribute somewhat to the cementation of these rocks.

A study of the relationship between detrital grains shows that quartz and potash feldspars are almost equally resistant to solution, and for this reason the contacts between them are usually conformal and, less commonly, microstylolitic (Figure 1). The plagioclase grains are less stable and are usually considerably more dissolved at the contacts with quartz and quartzite grains. For this reason, besides the conformal incorporation structure these rocks exhibit imbedded structure with these grains being intruded into the plagioclase. The fragments of phyllite shale and mica schist undergo intensive plastic deformation and partial solution (Figure 2). The grains of quartz-mica and quartz-chlorite schists are less resistant to solution and at contacts quartz, quartzite and potash feldspar fragments are imbedded in them.

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[3]By idioclastomorphism I mean the ability of a grain to preserve its detrital form in solution structures; and by xenoclastomorphism, the lack of this ability.

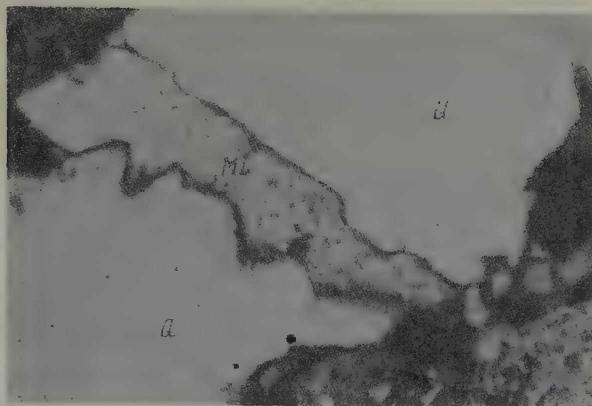

FIGURE 1. Microstylolitic structure in polymict sandstones.

Q - quartz; Mi - microcline. Crossed nicols, x 90. Shebelinsk gas field.

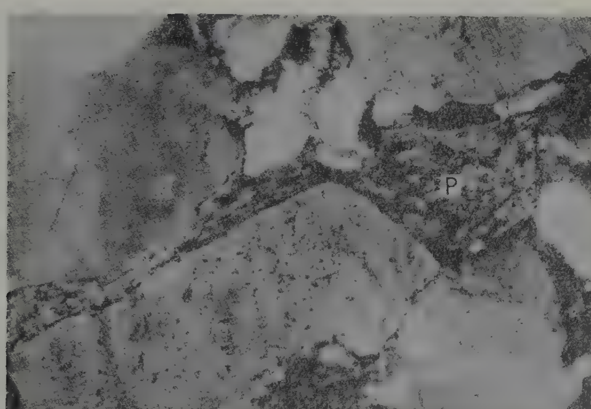

FIGURE 2. Plastic deformation and partial solution of a phyllite fragment.

Q - quartz, Mi - microcline, P - phyllite. Crossed nicols, x 75. Shebelinsk gas field.

The microgranular siliceous sedimentary rocks behave in different ways. The colorless varieties dissolve rather readily and are intruded by quartz and feldspar (Figure 3). The yellowish and brownish varieties containing hydrous iron oxides are more resistant and form conformal contacts with quartz and feldspar and sometimes even intrude these minerals. Fragments of holocrystalline volcanic rocks are approximately as resistant to solution as quartz and potash feldspars, but intermediate and basic extrusive rocks containing glass are very easily dissolved and usually exhibit strong xenoclastomorphism in relation to the other detrital components. They seldom preserve their original shape and their form in the rock is governed entirely by the shape of the adjacent and imbedded grains. Often they acquire intricate shapes characteristic of cements filling pore spaces.

The secondary minerals which are associated with these textural changes are quartz and chlorite. Quartz forms secondary overgrowths on detrital grains which frequently extend into adjacent pores. Chlorite forms rims on detrital grains, fills small porous areas, and penetrates into grains of different minerals along

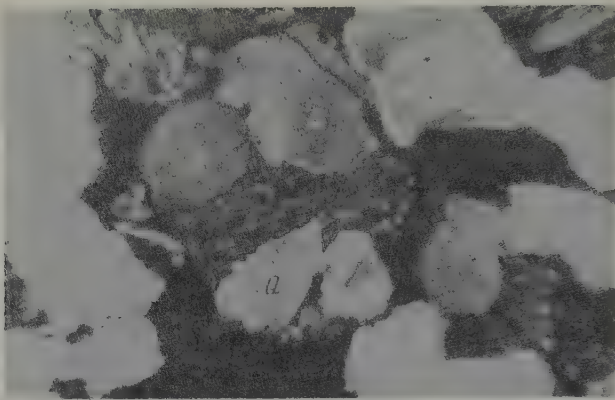

FIGURE 3. Incorporation of quartz grains (Q) into a chert grain.

Crossed nicols, x 45. Shebelinsk gas field.

cleavage cracks and replaces them. Muscovite is sometimes formed at the expense of potash feldspars.

Structures like these were observed by the author in the pre-Ordovician sandstones of the Ashinsk formation on the western slopes of the Urals (collected by B.M. Keller). Besides quartz and a small smount of potash feldspar, these polymict rocks contain abundant fragments of chert, quartzite, hornfels, quartz-chlorite, quartz-sericite, quartz-muscovite, mica-quartz and mica schists, phyllite, extrusive rocks of different composition and texture and, less commonly, of limestones. Flakes of chlorite and grains of epidote also are present. The development of conformal, less frequently microstylolitic and imbedded structures welds individual grains into continuous pseudogranoblastic aggregates composed of various minerals and rocks of different composition and texture.

By examining the relationship among grains and lithic fragments in the rock it is possible to detect the differences in their resistance to solution. The most stable are quartz, potash feldspars, quartzites and hornfels grains; the less stable are light-colored cherts and schists (Figures 4 and 5). The grains of limestone and volcanic rocks are usually even more easily dissolved, the resistance of the latter increasing with the degree of their crystallinity.

The most soluble detrital components are volcanic glasses. The glassy mesostasis of volcanic rocks dissolves differentially, the silicate components of glass dissolving more easily than the iron compounds present in it. As the grains of volcanic rocks undergo solution they become enriched in iron, grow darker in color, lose transparency and pass into almost silicate-free ferruginous material containing relatively insoluble crystalline components, the plagioclase microlites (Figure 6). The removal of the silicates from the glass diminishes the volume of the grains and they assume intricate shapes under the pressure exerted on them by the adjacent grains.

Some varieties of sandstones of the Ashinsk formation were not cemented at all. These initially uncemented rocks are held together mainly by the interpenetration of the grains produced by pressure solution and the development of microstylolitic, conformal and imbedded structures. Sometimes fragments of volcanic rocks (Figure 7), limestones and other easily soluble rocks serve as the cement. Secondary minerals formed as a result of solution: quartz in secondary overgrowths on the detrital grains, and sometimes albite, chlorite and calcite also acted as cementing agents. Chlorite and calcite not only rim the detrital grains and fill pores but also corrode mineral and lithic fragments. Sometimes authigenic muscovite develops at the grain contact. A very common secondary material is hydrous iron oxide, which forms films in the areas of contact and mutual solution of the grains.

The solution structures of the microstylolitic, conformal and less frequently imbedded types are rather frequently found in the Lower Carboniferous polymict sandstones of Tuva (collected by M.I. Grayzer and I.S. Borovskiy). Besides quartz and feldspars these rocks contain large, sometimes predominant amounts of fragments of acid, intermediate and basic volcanic rocks, chert, chalcedony, quartzite, hornfels, quartz-sericite and quartz-chlorite schists and sometimes of limestones. Micas

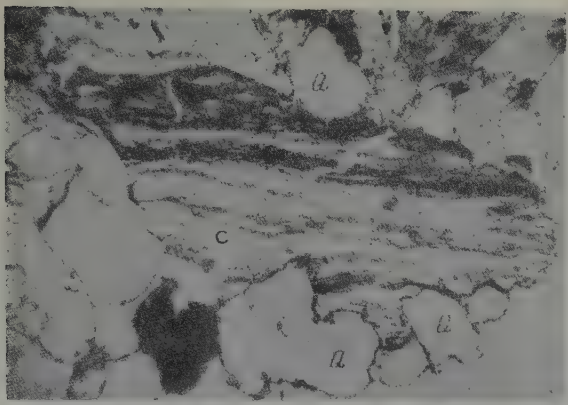

FIGURE 4. Incorporation of quartz grains (Q) into a grain of chert (C).

Without analyzer, x 39. Ashinsk formation, Urals.

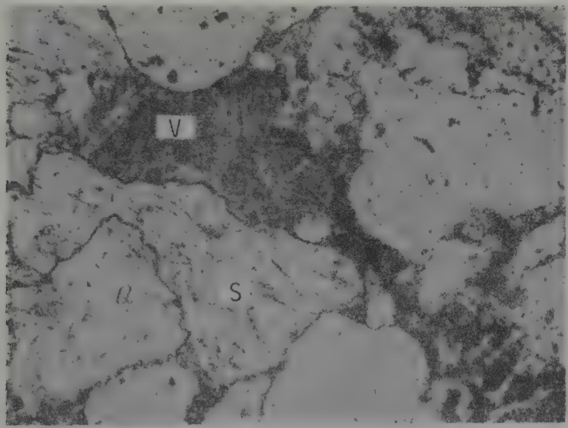

FIGURE 5. Incorporation of quartz grains (Q) into quartz-mica schist (S) and a fragment of volcanic rock (V).

Without analyzer, x 39. Ashinsk formation, Urals.

and chlorite are present sparingly. Some varieties contain small or occasionally substantial admixtures of volcanic ash.

Here also, although not as clearly as in the sandstones of the Ashinsk formation, the differences in the resistance of the detrital components to solution are apparent. The most stable are quartz and potash feldspars, then the fragments of chert and schists, and finally the relatively easily soluble basic volcanic rocks and volcanic glasses.

The fragments of basic volcanic rocks clearly show preferential solution of the silicate material and substantial enrichment of deformed grains in iron. The secondary minerals associated with these structural changes are mainly quartz and albite regenerating the detrital grains and, less frequently, pore fillings of iron oxides, calcite, chlorite, zeolites, chalcedony and, rarely, muscovite. Authigenic titanium minerals and epidote occur in small amounts.

In describing the Lower Cambrian polymict sandstones of the Srednevitim mountainous region (Padar sequence), L.I. Salop [3] noted that "the rounded fragments of different rocks and minerals penetrate deeply into the angular

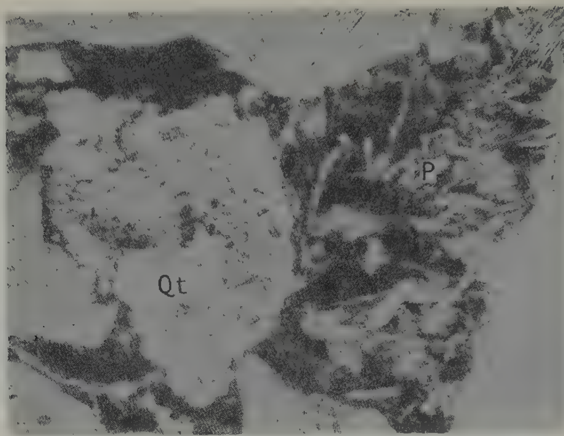

FIGURE 6. Incorporation of quartzite grain (Qt) into a fragment of porphyrite (P).

Without analyzer, x 58. Ashinsk formation, Urals.

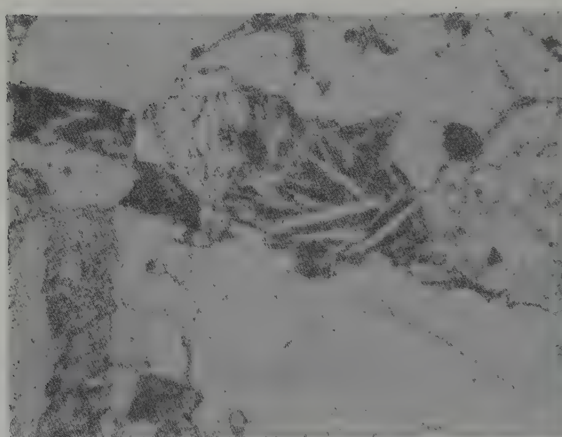

FIGURE 7. Xenoclastomorphism in a grain of volcanic rock.

Without analyzer, x 58. Ashinsk formation, Urals.

fragments of the microfelsitic or glassy mesostasis of acid volcanic rocks, and the fragments hold them so tightly that they play the role of a cementing material." Salop explains this relationship by saying that hot, still plastic fragments of lava fell on the sand and gravel accumulations derived from the erosion of lavas and tuffs and bound the water deposited fragments of different rocks. However, his description and photographs leave no doubt that epigenetic selective solution of volcanic glass fragments must have taken place here with the formation of typical imbedded structures.

Extremely interesting are the structural and mineralogical transformations in pyroclastic rocks. It should be noted that many tuffs, although their constituent fragments are intricate in form, often veicular and usually not rounded or only slightly so, all features contributing to high porosity, usually have low total and effective porosity. The second characteristic of tuffaceous rocks is the intensity of their alteration resulting in abundant development of a number of secondary minerals, quartz, chalcedony, albite, chlorite, zeolites, prehnite, epidote, zoisite, hematite,

calcite and many others which in some cases completely replace the original material.

Most investigators consider that these alterations are caused by late magmatic and hydrothermal activity. Others believe that tuffs are altered by the action of either emanations or juvenile waters related to the volcanic activity responsible for the deposition of ash.

In many cases factual data are not in agreement with these concepts. First of all, let us note that the beds of strongly altered tuffs are frequently interbedded with limestones which show no signs of metamorphism. Such selective alteration affecting the tuffs only cannot be a result of magmatic and hydrothermal activity, for in that case the interbedded sedimentary rocks would have been affected also. The alteration cannot be ascribed to autometamorphism, because strongly altered tuffs are often found at a considerable distance (hundreds of kilometers) from the source of eruption in subaqueous deposits containing faunas testifying to the normal hydrochemical water regime in the basin of deposition.

What, then, is the cause of alteration of pyroclastic deposits?

Microscopical investigations of pyroclasts from many regions show that solution structures are widely developed in them. The shards of the groundmass form aggregates in which the outlines of the adjacent shards are strictly preserved, the contacts are smooth and linear, the contacting surfaces are large and the pores are relatively few. If it is considered that the original form of the shards was very irregular, then these contacts undoubtedly must be due to the solution of the fragments at the points of contact and to mutual accommodation of their shapes, i.e., to the development of conformal structure. Comparing the probable initial size of the shards with their size after solution, it is not difficult to be convinced that the amount of dissolved material was very large, several tens per cent of the original clastic material in the deposit. Depending on the chemical composition of the pyroclastic material in a deposit, its textural characteristics affecting the intensity of solution, the depth of burial, the chemical character of pore solutions and other factors, certain minerals will form, cementing the rock and replacing the crystals and lithic fragments.

In the vitric and fine-grained lithic tuffs of Tuva and Minusa, composed of glass shards and fragments of rhyolitic lavas (collected by M.I. Gayzer and N.S. Borovskaya), the alteration consists in silicification, formation of porcellanitic quartz and chalcedony, albitization, chloritization and, more rarely, zeolitization.

According to N.G. Brodskaya, in the Tertiary tuffs of Sakhalin, composed mainly of andesite glass, the consequence of solution resulting in conformal and imbedded structures is the formation of ferruginous, chloritic and carbonate cement, of epidote and zoisite and sometimes of zeolites.

In the Silurian tuffs of the southern Urals, composed of albitophyre and andesite glass, conformal and imbedded structures are widely developed and are accompanied by antinolitization, epidotization, chloritization, prehnitization and the development of a number of other secondary minerals.

The data cited in this paper show that epigenetic solution structures induced by pressure are very widely developed in clastic rocks of different types and formed under different tectonic conditions. Casually related to the development of these structures is the appearance of peculiar mineral parageneses not usually found in sedimentary rocks. These minerals crystallize from solutions and are produced also by metasomatic action of the solutions on the clastic particles. The composition of these secondary minerals depends on the primary composition of the rock.

REFERENCES

1. Kopeliovich, A.V., O mikrostilolitakh i nekotorykh rodstvennykh im strukturnykh formakh v peschanikakh mogilevskoy svity yugo-zapada Russkoy platformy. [ON MICROSTYLOLITES AND RELATED STRUCTURES IN THE SANDSTONES OF THE MOGILEV FORMATION SOUTHWEST OF THE RUSSIAN PLATFORM]: Doklady, Akad. Nauk SSSR, t. 119, no. 2, 1958.

2. ___________, Osobennosti epigeneza peschanikov mogilevskoy svity yugo-zapada Russkoy platformy i nefotoryye voprosy s nimi svyazannyye. [CHARACTERISTICS OF EPIGENESIS OF THE MOGILEV FORMATION SANDSTONES IN THE SOUTHWEST OF THE RUSSIAN PLATFORM AND SOME PROBLEMS RELATED TO THEM]: Izvestiya, Akad. Nauk SSSR, ser. geol., no. 11, 1958.

3. Salop, L.I. Nizhniy paleozoy Sredne-Vitimskoy gornoy strany. [LOWER PALEOZOIC OF THE MIDDLE VITIM MOUNTAINOUS REGION]: VSEGEI. Gosgeolizdat, 1954.

4. Gilbert, Ch.M., Cementation of some California tertiary reservoir sands. J. Geol., vol. 57, no. 1, 1949.

5. Heald, M.T., Stylolites in sandstones. J. Geol. vol. 63, no. 2, 1955.

6. Lowry, W.D., Factors in loss of porosity by quartzose sandstones of Virginia. Bull. Amer. Assoc. Petrol. Geologists, vol. 40. no. 3, 1956.

7. Sloss, L.L. and D.E. Feray., Micro-stylolites in sandstone. J. Sedim. Petrol., vol. 18, no. 1, 1948.

8. Taylor, I.M., Pore-space reduction in sandstones. Bull. Amer. Assoc. Petrol. Geologists, vol. 34, no. 4, 1950.

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FORMATION OF HALOGENIC ZONES IN MARINE BASINS ILLUSTRATED BY THE EXAMPLE OF THE LOWER CAMBRIAN EVAPORITE BASIN OF THE SIBERIAN PLATFORM[1]

by

N. A. ARKHANGEL'SKAYA AND V. N. GRIGOR'YEV

On the basis of material obtained during a study of the Lower Cambrian deposits of the southern and western parts of the Siberian Platform the authors conclude that in an arid climate a halogenic zone may form within an extensive shallow water basin without being isolated by barriers but merging gradually into the areas of normal salinity.

* * * * *

A study of the lithology and facies of the Lower Cambrian deposits on the southern and western borders of the Siberian platform revealed a number of peculiarities of sedimentation in the basin of that age. Of the greatest interest are the conditions of formation of salt deposits which form the subject of this paper.

The Lower Cambrian stratigraphy of the Siberian platform is sufficiently well known now to serve as a basis for paleogeographic and facies reconstructions. As a result of the work of a large group of geologists [3, 5, 9, 13, 16, 20, 25], a unified stratigraphic column has been constructed for the Cambrian period. Using it as a base and taking the lithological data into account, we correlated the Lower Cambrian sections of the entire investigated territory beginning with the Zhura substage (Figure 1). The correlation chart shows that the salt-bearing deposits are restricted to three stratigraphic levels, the Ketema and Tolbachan horizons and the Zhura substage.[2]

The Lower Cambrian strata of the Siberian platform are mainly carbonate rocks, fine-grained and cryptocrystalline dolomites being the most widespread. The uniformity of their texture and composition over long distances leaves no doubt that they are primary dolomites.

Among the limestones, homogeneous microgranular and fine-grained aphanitic limestones are predominant and they also are of chemical origin.

Very common are carbonate rocks of mixed calcitic and dolomitic composition, which are represented by homogeneous and spotted varieties. In the former, usually microgranular or fine-grained, the grains of calcite and dolomite are uniformly distributed through the rocks. The dolomite grains are usually somewhat larger than the calcite grains, but not infrequently the grains of both minerals are alike in form and size and can be distinguished in thin sections only by staining. The relative amount of calcite and dolomite in different beds varies within broad limits and the rocks form a continuous series from slightly dolomitic limestones to slightly calcitic dolomites. These rocks were evidently formed as a result of simultaneous accumulation and precipitation of calcite and dolomite crystals in the chemical sediment. The spotted textures resulted from diagenetic redistribution of the materials in these sediments.

Phytogenic sediments such as stromatolitic and oncolitic limestones, dolomites and intermediate carbonate rocks are widespread in the Lower Cambrian. They also are essentially chemical deposits but formed by the biological activity of blue-green algae. Zoogenic rocks such as archaeocyathid and fossil detritus limestones are exceptionally rare in the Lower Cambrian.

Side by side with the carbonate rocks an important role in the Lower Cambrian sections is played by such obviously chemical precipitates as gypsum, anhydrite and rock salt, and mixed carbonate-sulfate rocks (anhydrite-dolomite) are of frequent occurrence.

Besides the carbonate and salt deposits, the

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[1]Usloviya obrazovaniya solerodnykh zon v morskikh vodoyemakh na primere Nizhnekembriyskogo evaporitovogo basseyna Sibirskoy platformy.

[2]Some investigators [13] refer the lower salt-bearing beds in the Irkutsk amphitheatre (the Usolka formation) to the Sinian age.

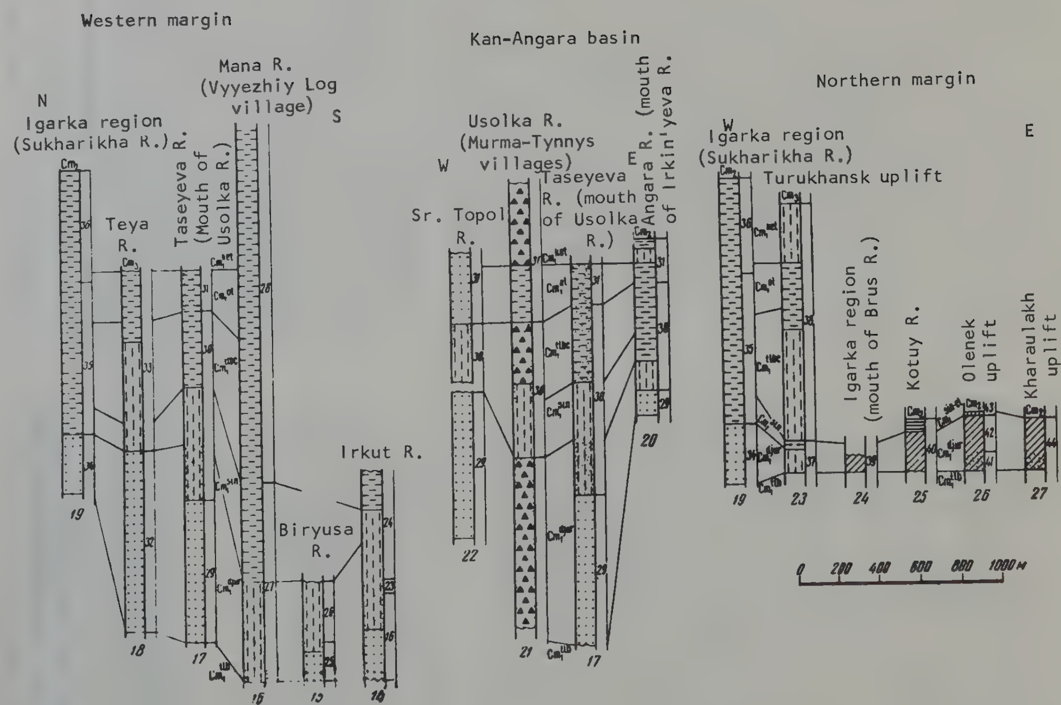
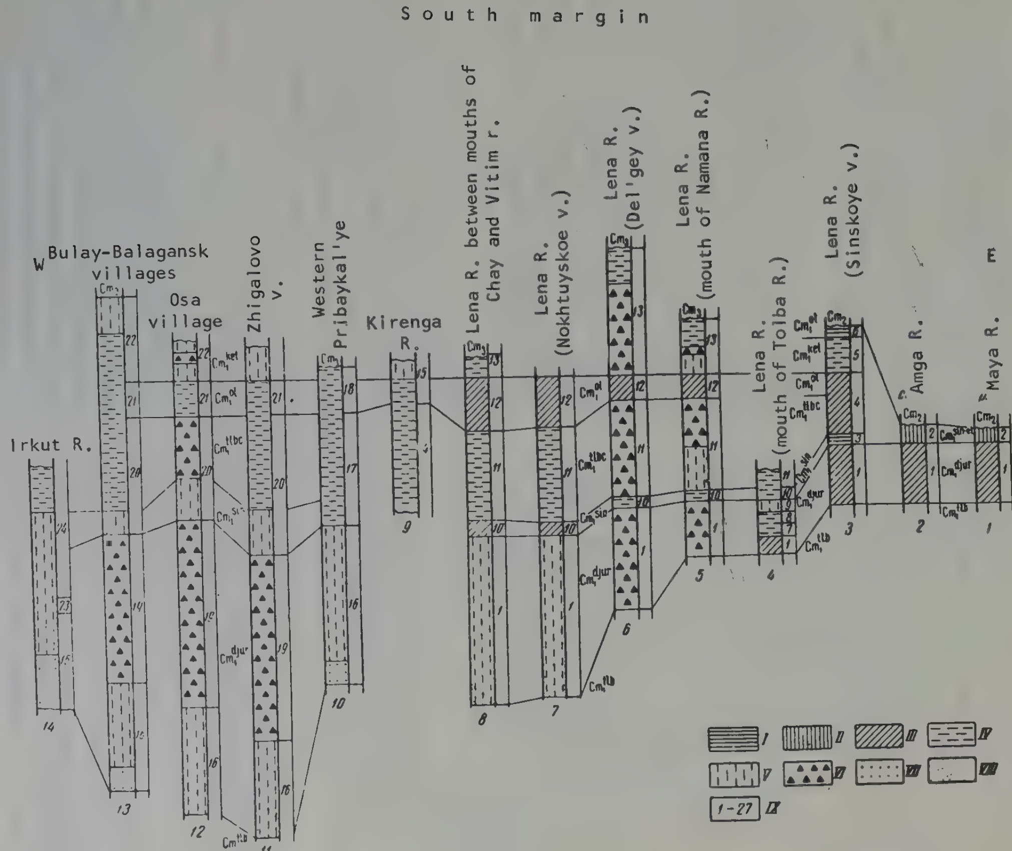


FIGURE 1. Correlation and facies of the Lower Cambrian deposits of the Siberian platform.

Facies: I - facies of normal salinity; II - same facies, thin deposit; III - facies of nearly normal salinity; IV - facies with salinity transitional from normal to high; V - facies of high salinity; VI - salina facies; VII - terrigenous nearshore facies of marine basin; VIII - considerable admixture of terrigenous material in evaporite beds; IX - numbers of exploratory boreholes.

Stratigraphic subdivisions: Aldan stage: Cm_1^{tbl} - Tolbinsk substage, Cm_1^{djur} - Zhurinsk substage. Lena stage: Cm_1^{sin} - Sinskaya zone, Cm_1^{tlbc} - Tolbachan zone, Cm_1^{ol} - Olekma zone, Cm_1^{ket} - Keteminsk zone, Cm_1^{el} - Yelanskoye zone.



Formations (subformations, members, zones): 1 - Variegated; 2 - Inikan, 3 - Sinskaya, 4 - Kutorgina, 5 - Keteminskaya, 6 - Yelanskaya, 7 - Nokhoroyskaya, 8 - Churanskaya, 9 - Malykanskaya, 10 - El'gyanskaya, 11 - Tolbachansk, 12 - Olekma, 13 - Charsk, 14 - Tukolonskaya, 15 - Munokskaya, 16 - Motskaya, 17 - Ungurinskaya, 18 - Kamenskaya, 19 - Usol'skaya, 20 - Bel'skaya, 21 - Bulayskaya, 22 - Angara, 23 - Perekhodnaya, 24 - Vvedenskaya, 25 - Ust'-Tagul'skaya, 26 - Tal'skaya, 27 - Zhershul'skaya, 28 - Kolbinskaya, 29 - Shalyginskaya, 30 - Klimenskaya, 31 - Agalevskaya, 32 - Nemchanskaya, 33 - Lebyazhinskaya, 34, Izluchinskaya, 35 - Sukharinskaya, 36 - Rechkinskaya, 37 - Platonovskaya, 38 - Kostinskaya, 39 - Ust'-Brusskaya 40 - Ust'-Kotuykanskaya, 41 - Kesyusinskaya, 42 - Yerkeketskaya, 43 - Kuonamskaya, 44 - formation G (zones b - d - e).

Lower Cambrian contains great thicknesses of purely continental deposits, but they occur only in some areas of the southwestern border of the Siberian platform in the lower part of the Cambrian section (Zhura substage). They were formed, evidently, as a result of erosion of mountains which existed at that time in these areas.

Inasmuch as most Lower Cambrian sediments are obviously chemical and the determining factor in their deposition was the degree of salinity of the basin of sedimentation, it is precisely this factor that must be taken as the basis for separating the different facies of the Lower Cambrian sediments.

It is necessary to consider the criteria needed for accurate determination of the relative salinity of a basin. First of all, salinity is reflected in the composition of the sediments. For example, a direct proof of the high salinity of a basin is the presence of sulfates and halite, because gypsum begins to preceipitate from sea water only when salinity reaches 13%, and halite when it reaches 27%. The effect of change in salinity on the composition of marine faunas is also well known. An attempt was made to determine the relation between the composition of the Lower Cambrian carbonate rocks and the character of their faunas. As an example, we selected the Lower Cambrian section of the northeast part of the Aldan massif, composed entirely of carbonate rocks and abundantly fossiliferous. It was found that the number of species of trilobites, brachiopods, pteropods and sponges, and the total amount of organic remains are inversely proportional to the average dolomite content in the rocks, so that when this relationship is represented graphically, the curve of content of primary dolomite in the section is a mirror image of the curve representing the total number of the organisms listed above. This indicates that the variation in the dolomite content may be regarded as a clue to the variation in the salinity of a basin equal in value to the faunal change and the content of sulfates and halite.

Using these criteria, obtained by a detailed lithological study of the Lower Cambrian rocks of the Siberian platform, we distinguished a number of facies:

The marine facies characteristic of basins of normal salinity is represented by pure limestones. Here dolomite is exceptional and the sediments contain a rich and varied fauna.

The facies of the zone with nearly normal salinity is also represented by limestones but beds of mixed calcite-dolomite composition are present. The faunal assemblage in these deposits is somewhat less varied than in the preceding facies and the fossils are less abundant.

The facies of the zone of intermediate salinity forms a series illustrating gradually increasing salinity of a basin. This zone is characterized by the presence of pure limestones, mixed carbonate rocks and pure primary dolomites. The proportions of different rocks and the dolomite content vary within broad limits. The intermediata zone is poor in organic remains and the intermediate and extreme members of the salinity series contain only a few species with the individuals being small and obviously stunted.

The facies of the zone of high salinity contains a variety of primary dolomites. Limestones are exceptional and gypsum and anhydrite are occasionally found. No fossils have been found in this zone.

The halogenic zone facies. In this zone we placed all facies containing various salt deposits from dolomites interbedded with gypsum and anhydrite to deposits containing rock salt as the principal constituent.

Besides these facies characteristic of the entire Lower Cambrian, there are others more restricted in time. For example, in the deposits of the Zhura substage there is a group of nearshore marine facies represented by molasse-like deposits of red ripple-marked and cross-bedded polymict sandstones and siltstones with admixed coarse material.

In the Lena stage a special facies must be separated among the facies of the zone of normal salinity occurring only in the eastern border of the Siberian platform and distinguished by a sharply diminished thickness. It is represented by black stongly bituminous (up to 10% organic carbon) rocks, shaly limestones and silty marlstones containing thoroughly silicified beds. These rocks are very similar to the bituminous limestone of the Sinian formation (facies of normal salinity), differing from them mainly in the rather high content of quartzitic silt and intensive silicification [6].

But while the Sinian limestones, about 40 m in thickness, contain a rich fauna correlatable only with the base of the Lena stage (Sinian horizon), the sediments of the facies under discussion, although of the same thickness, contain fossils from almost all horizons of the Lena stage; i. e., they correspond in age to the multifacies sequence of rocks from 350 to 600 m in thickness [15, 24, 25]. At present there is no explanation for this great reduction in thickness.

A characteristic feature of the Lower Cambrian basin as a whole was its shallowness. In the deposits of the normal and nearly normal salinity this is indicated by the presence of bioherms of archaeocyathids and epiphytic algae. The sediments from the zones of higher salinity, including the halogenic zone, contain numerous

oncolites and stromatolites. It must be concluded from this that the average depth of the Lower Cambrian basin did not exceed 30-50 m. At such depth wave action could easily affect the bottom of the sea and produce ripple marks and in the molasse-like sands of the nearshore zone and in some carbonate sediments of the other zones. Wave action explains also the occasional destruction of the archaeocyathid and algal bioherms and the formation of interformational breccias. Only the facies with reduced thickness were deposited at a considerably greater depth, as indicated by the very thin unbroken laminations of the rocks and the preservation of a large amount of organic material.

parts of the platform where the Lower Cambrian deposits are covered by younger rocks are tentative.

At present a considerable amount of material is available indicating that in the Zhura time the Lower Cambrian basin of the Siberian platform was bordered by a sea in the south and west (Figure 2). The southeastern parts of the platform were evidently strongly peneplaned by this time, but high mountainous relief still existed in the west. In the north, northeast and east, the Zhura substage of the platform is characterized by deposits of the zone of nearly normal salinity (the Anabar massif and the

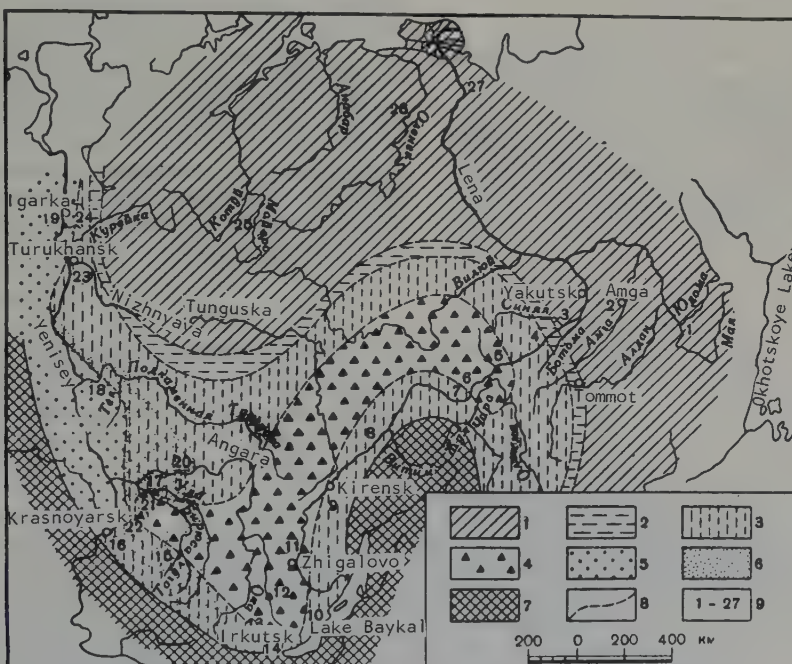


FIGURE 2. Distribution of facies on the Siberian platform in Zhura time.

1 - facies of nearly normal salinity; 2 - facies with salinity transitional between normal and high; 3 - facies of high salinity; 4 - salina facies; 5 - terrigenous nearshore facies of marine basin; 6 - area of evaporites with a considerable admixture of terrigenous material; 7 - strongly dissected provenance areas; 8 - zone boundaries; 9 - numbers of exploratory boreholes.

We have studied the distribution of the Lower Cambrian facies on the southern and western borders of the Siberian platform, and constructed schematic facies maps for all stratigraphic horizons. On the basis of these maps and the geological data on the northern regions published by a number of investigators [4, 11, 15], the Zhura substage and Lena stage facies maps were drawn for the entire Siberian platform. The boundaries of the facies zones in the central

eastern part of the Aldan massif). To the south and southwest they are succeeded by deposits of zones of increasing salinity, including the halogenic zone. As the map shows, these zones occupy a vast territory more than 2000 km long and not less that 200 km wide. Farther, in the belt adjacent to the land, salt deposits are followed again by the deposits of the zone of high salinity. To the west of the Anabar massif, salinity also increases but salt deposits are

absent and the sediments of the zone of high salinity pass into the nearshore molasse sediments.

The transitions between the sediments of the different zones are always gradual and consist in the change of composition of the rocks and their faunas. Especially characteristic of the transitional areas are various mixed rocks, dolomitic limestones, calcitic dolomites, anhydrite-dolomites, etc. All this indicates that in the Zhura time a single marine basin existed in the region of the Siberian platform in which the degree of salinity increased gradually from the open northeastern parts of the basin to the northwest in the direction of the nearshore areas and decreased again in the relatively narrow littoral zone.

This regularity in the succession of the zones was retained in a general way by the basin of the Lena time (Figure 3). But the distribution of the zones of different salinity during this time was considerably different as compared with the Zhura time. The zone of sediments deposited in water of high salinity was sharply diminished. Widespread over the entire northeast and east of the Siberian platform are rocks typical of the zone of normal salinity, absent from the deposits of the Zhura substage. In the extreme northeast and east these deposits are unusually thin. To the south and southwest they are replaced by sediments deposited in water of nearly normal and intermediate salinity. These are the most widespread rocks of the Lena stage in the southwestern half of the Siberian platform. Among them in a number of areas are deposits of the halogenic zone bordered by those of the zone of high salinity. As can be seen from Figure 3, these areas lie within the region occupied by the halogenic zone in the Zhura time.

There are no reasons to believe that the geographic setting was different in the Lena time as compared with the Zhura time. The land areas in the south were evidently subjected to more peneplanation. A very noticeable contribution of terrigenous material continued only in the southeast of the Yenisey range.

Individual areas of the peneplaned land were apparently gradually submerged by the continuing marine transgression and a connection

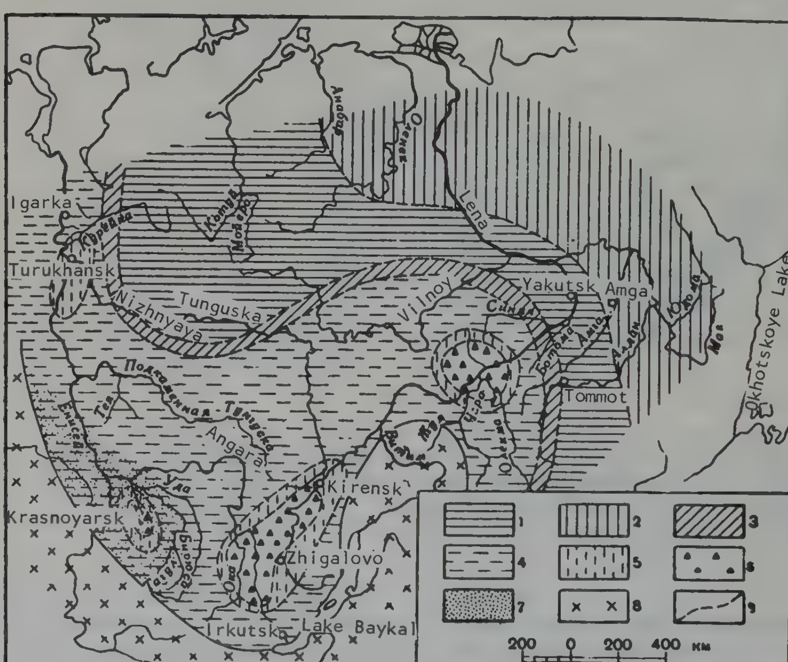


FIGURE 3. Distribution of facies on the Siberian platform in Lena time.

1 - facies of normal salinity; 2 - same facies, thin deposits; 3 - facies of nearly normal salinity; 4 - facies with salinity transitional between normal and high; 5 - facies of high salinity; 6 - salina facies; 7 - areas of evaporites with a considerable admixture of terrigenous material; 8 - peneplaned land areas; 9 - zone boundaries.

formed at this time between the platform sea and the geosynclinal basin lying to the south and southwest. The most complete interchange of water between them began at the very end of the Lower Cambrian as indicated by the presence of similar faunas in the Elanka horizon developed in both basins [14, 23].

Thus, during the entire Lower Cambrian the bast territory of the Siberian platform was occupied by a single very shallow epicontinental sea open to the north, northeast and east. Intensive chemical precipitation occurred everywhere in the basin and its cause must be sought in the increased salinity of the sea water produced by evaporation in an arid climate. This basin may be called an evaporite basin.[3]

It has been mentioned already that the characteristic feature of the Lower Cambrian basin is the gradual change from normal sediments to rock salt, indicating that sedimentation occurred in marine basins of different salinity. The rock salt and the other sediments were deposited in definite areas of the sea, yet there are no abrupt changes suggesting the existence of bars at the boundary between the halogenic zone and the rest of the basin nor any other indications that this zone was an isolated part of the sea during the Lower Cambrian.

To gain a better understanding of the characteristics of sedimentation in the investigated region we must consider the processes causing variation in salinity in shallow basins in general. It is convenient to review these processes one by one and then compare their results.

The fundamental cause of increased salinity of water is evaporation. If, in an evaporite basin freely communicating with the world ocean, evaporation exceeds precipitation, water will flow from the ocean in a slow compensational current and equalize the hydrostatic level. This ocean water will bring new portions of salt into the basin and as a result its area of water of high salinity will increase. Evaporation increases salinity of the surface layer only. But storms mix surface water with the water of the underlying layers and salinity becomes averaged to the depth of wave action, i. e. through the entire depth of a very shallow basin (30 - 50 m).

Let us try by means of a very approximate calculation to determine the character of change in salinity in a shallow evaporite basin receiving water from the ocean. To simplify the problem we shall take a rectangular area of the basin bounded by the shore on one side (section ABCD) and receiving a compensational flow of sea water of normal salinity through section ($A_0B_0C_0D_0$) (Figure 4). Let h be the average depth of the evaporite basin, assumed to be constant, and a the width of the rectangular area of the basin. The distance from the shore to the part of the basin in which salinity is not increasing, i. e. the length of the evaporite basin, will be designated by L. The excess of evaporation over atmospheric precipitation for a given period of time per unit area, q, will be considered constant for the whole evaporite basin.[4]

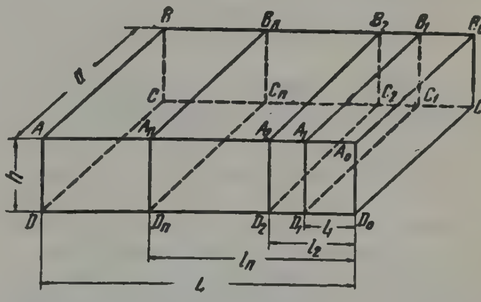


FIGURE 4. Principal parameters of a basin used in calculating the magnitude of compensational flow.

The total amount of water carried by the compensation current through the section $A_0B_0C_0D_0$ during a given period of time must equal the amount of water lost by evaporation during the same time from the entire ABB_0A_0 area. The loss of water is given by product qaL. It is easy to calculate the amount of water (U_0), flowing through a unit area of section $A_0B_0C_0D_0$ in unit time:

$$U_0 = \frac{qaL}{ah} = \frac{qL}{h}. \qquad (1)$$

As the evaporating area decreases, the amount of water flowing through the unit area in every successive section must also decrease.

Thus, in section $A_1B_1C_1D_1$ (1a)

$$U_1 = \frac{qa(L-l_1)}{ah} = \frac{qL}{h}\left(1-\frac{l_1}{L}\right) = U_0\left(1-\frac{l_1}{L}\right).$$

In section $A_2B_2C_2D_2$

$$U_2 = \frac{qL}{h}\left(1-\frac{l_2}{L}\right) = U_0\left(1-\frac{l_2}{L}\right). \qquad (1b)$$

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[3]By an evaporite basin we understand an extensive part of a marine basin in which increased evaporation causes chemical precipitation of all salts from carbonates and sulfates to halides. This definition differs from that accepted abroad [27, 28], where the term "evaporite basin" is restricted to areas of precipitation of sulfates and rock salt, i.e. specifically to halogenic basins.

[4]Actually, as the salinity of the water increases, all other conditions being the same, its capacity to evaporate decreases, and within the limits of salinity considered here this decrease may amount to 25%.

In section $A_nB_nC_nD_n$

$$U_n = \frac{qL}{h}\left(1 - \frac{l_n}{L}\right) = U_o\left(1 - \frac{l_n}{L}\right). \quad (1c)$$

Unlike the amount of water, the amount of dissolved salts J_k carried by the compensation current through unit area in unit time remains constant in each successive section ($A_oB_oC_oD_o$ and $A_1B_1C_1D_1$, etc.) provided no salt is precipitated. This may be written:

$$J_k = S_oU_o = S_1U_1 = S_2U_2 = \ldots = S_nU_n, \quad (2)$$

where $S_{o,1,2,\ldots,n}$ is salinity in each successive section.

From expression (2) it follows that:

$$U_n = \frac{S_oU_o}{S_n}. \quad (2a)$$

Substituting the values of U_o and U_n in (2a) and simplifying, we obtain the following expression:

$$l_n = L\left(1 - \frac{S_o}{S_n}\right). \quad (3)$$

Therefore, the distance at which salinity will rise to a given value, measured from the beginning of the evaporite basin, depends on the initial salinity (S_o) and on the entire length of the evaporite basin (L), and is independent of the average depth (h) and the excess of evaporation over precipitation (q) if these values are constant for the whole basin. The magnitude of h and q will affect only the time needed to raise the salinity of the basin to a given level.

Using equation (3) it is easy to calculate l_n for any preassigned salinity (4%, 5%, 6%, etc.). The composition of ocean water of different concentration and the degree of salinity required for precipitation of gypsum, halite, epsomite and potassium salts are known from the work of M. G. Valyashko ([2] and Table 1). The value of l_n can be calculated for each of these salinities. For example, for the beginning of precipitation of gypsum (S = 13.14%), l_n' = 0.73L; for that of halite, it is 0.87L; for epsomite, 0.97L; and, finally, for the precipitation of potassium salts (sylvite), l_n = 0.977L.[5]

The values of l_n were used to construct a graph showing variation in the total salinity of water over the area of the evaporite basin in the direction of the compensation current. This graph is given in Figure 5. The values of l_n expressed in fractions of L taken as unity were plotted on the axis of the abscissas and total salinity in precent was plotted on the axis of the ordinates.

The graph shows that the salinity of the evaporite basin does not change uniformly in the direction of the compensation current but increases more and more sharply. Especially sharp is the increase within the halogenic zone. The graph shows also that the precipitation of the salts beginning with calcium sulfate (in the halogenic zone as we define it) is restricted to a zone whose width is small as compared with the area of the evaporite basin, and in the case of a single compensational current it hugs the shore. The smaller the area of the evaporite basin, the narrower is the halogenic zone.

It is easy to show that in the case of two equal and opposite currents the halogenic zone will form in the central part of the basin and the graph of salinity change will be symmetrical. If the two currents are not equal in their effect, for example if the depth of the evaporite basin

Table 1

Composition of Ocean Water at Different Degrees of Concentration in grams per 1000 g of water (after M. G. Valyashko [2])

Degree of concentration of ocean water	$CaCO_3$	$CaSO_4$	$MgSO_4$	$MgCl_2$	Na Cl	K Cl	NaBr	Total salts
Normal ocean water	$Ca(HCO_3)_2$ 0.134	1.276	2.305	3.385	27.667	0.763	$MgBr_2$ 0.092	35.62
Beginning of precipitation:	$MgCa(HCO_3)_2$							
gypsum	0.340	4.90	9.50	14.90	99.10	2.40	0.26	131.40
halite	0.52	0.460	21.0	33.40	214.10	5.20	0.59	275.27
epsomite	2.24	Traces	89.2	158.2	50.50	22.90	2.72	325.70
sylvite	Not det.	"	75.5	169.1	33.80	49.2	Not det.	327.60
carnallite	3.01	"	64.4	218.4	24.2	31.6	3.9	345.51

[5]In calculating l_n and contructing the graph, we considered the change in the primary proportion of salts in ocean water with rise in salinity only from the moment of precipitation of sodium chloride, for it is this salt that constitutes the bulk (77%) of dissolved solids.

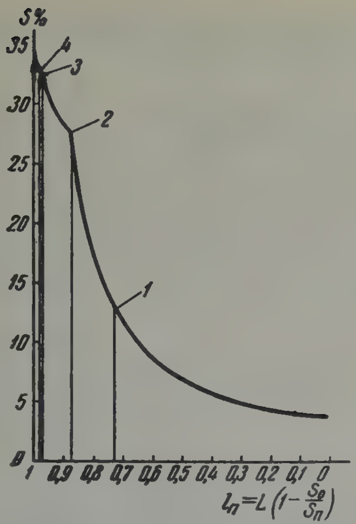

FIGURE 5. Variation in salinity of ocean water within an evaporite basin:

1 - beginning of precipitation of gypsum; 2 - beginning of precipitation of halite; 3 - beginning of precipitation of epsomite; 4 - beginning of precipitation of sylvite.

is not uniform, the halogenic zone will be shifted to one side or the other.

With equal flows from all sides, the halogenic zone in the ideal case will form a circular area in the center of the basin. Here, instead of formula (3), formula

$$l_n = R\left[1 - \left(\frac{S_0}{S_n}\right)^{\frac{1}{2}}\right], \qquad (4)$$

will apply, with R being the radius of the evaporite basin.

In nature if the shape of a shallow evaporite basin is intricate and the compensating currents reaching the halogenic zone from all sides are unequal, the zone may assume various forms and positions. Nevertheless, the areal relationships derived above for an elementary case should hold.

Let us estimate the amount of material carried by the compensation current. The value of J_k (expressed in terms of qL and h) is obtained from equation (2c):

$$J_k = \frac{q\,(L - l_n)\,S_n}{h}\ [\text{cm/sec}]. \qquad (5)$$

For our calculation we shall take q = 0.5 m/year = $\frac{1}{6.10^5}$ cm/sec*, h = 50m = 500 cm, S_n = 27‰.

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*This considerable excess of evaporation over precipitation is quite usual at present in the high pressure zones to the north and south of the equator.

It is easy to calculate that if L = 10 km, J_k = 0.0012 cm/sec, and that for L = 100 km, J_k is ten times as great (0.012 cm/sec), and for L = 1000 km, J_k is one hundred times as great (0.12 cm/sec). Equation (5) shows that there is an inverse relation between J_k and the depth of the basin h (as h increases by a certain factor, J_k decreases by the same factor).

As zones of different salinity, and therefore of different density, appear in the evaporite basin, processes tending to equalize these differences inevitably arise, i. e. diffusion and outflow of the more dense water. There are two types of diffusion. In a stationary medium only slow molecular diffusion occurs; in a mobile medium such as the water in natural basins the main role is played by the much more active turbulent diffusion always directed towards the zone of lower density.

In turbulent diffusion the transfer of matter through unit area per unit time, J_T, is proportional to the gradient of concentration [8]. For the area of the evaporite basin described above this may be written:

$$J_T = D_T \frac{\Delta S}{\Delta L}\ [\text{cm/sec}], \qquad (6)$$

where D_T is the coefficient of turbulent diffusion and $\frac{\Delta S}{\Delta L}$ is the salinity gradient.

It is very difficult to determine the value of D_T for turbulent diffusion because it depends on many variables and first of all on the magnitude known in hydraulics as the mixing length. When a liquid moves over a horizontal surface the mixing length is the depth of the basin. The larger the value of h, the larger is the coefficient D_T and therefore the larger is the value of J_T.

For a shallow basin, D_T is approximately a million times as great as the coefficient of molecular diffusion; i. e. it amounts to a few square centimeters per second. The experimentally determined coefficient of turbulent diffusion in some modern shallow basins equals 5 cm^2/sec [10]. In large basins it may be a hundred times greater (up to 500 cm^2/sec).

The value of the salinity gradient in different parts of an evaporite basin (i. e. over its length L), or in basins of different sizes, may easily be computed with the aid of the graph of Figure 5. The results are shown in Figure 2. The figures show that only when L is small does the salinity gradient for the cases of high salinity approach thousandths of one percent per centimeter. When values of L are of the order of several hundred kilometers, salinity gradients are quite insignificant.

Substituting D_T = 500 cm^2/sec and $\frac{\Delta S}{\Delta L}$ = 0.0003% cm^{-1} (the value of salinity gradient for high degree of salinity if L = 10 km) in equation (6), we have J_T = 0.15 cm/sec. If L = 100 km,

Table 2

Character of Variation of Salinity Gradient at Different Stages of Concentration with the Size of Evaporite Basin

L km	S % 26	23-25	21-22	19-20	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4
	Salinity gradients $\frac{\Delta S}{\Delta L}\left[\frac{\%}{cm}\right]\cdot 10^{-9}$																		
10	330000	166000	143000	111100	100000	83300	77000	71300	58800	52600	45400	37000	31200	26300	24100	15900	12500	8300	5700
500	6600	3320	2860	2222	2000	1666	1540	1426	1176	1052	908	740	624	526	482	318	250	166	114
1000	3300	1660	1430	1111	1000	833	770	713	588	526	454	370	312	263	241	159	125	83	57
2000	1650	830	715	555	500	416	385	356	294	263	227	185	156	131	120	79	62	41	28

J_T for the case of high salinity will be one tenth of this value (0.015 cm/sec) and for L = 1000 km, one hundredth (0.0015 cm/sec).

Comparison of expressions (5) and (6) and the numerical values obtained for J_k and J_T for different values of L leads to the conclusion that for relatively small values of L (of the order of tens or even hundreds of kilometers) or for a considerable depth of the basin (h = tens and hundreds of meters), $J_T \gg J_k$; and for large values of L (thousands of kilometers) and small h (up to a few tens of meters), $J_T \ll J_k$.

A comparison of expressions (5) and (6) shows also that the transfer of material by the compensation current J_k is directly proportional to the excess of evaporation (q), i. e. depends on climatic conditions, while the amount of material transferred by turbulent diffusion, J_T, is in no way related to q. Hence the hotter the climate and the larger the value of q, the greater the difference between J_T and J_k, other conditions being the same, and the sooner a halogenic zone will form in the basin and the more stable it will be.

Climatic changes disturbing the relation between J_k and J_T will cuase a change in salinity, and in the final analysis this must affect the character of the chemical sediments.

The second process arising with the appearance in the basin of zones of different salinity and density is the outflow of water in the near bottom parts of the basin from the areas of greater density to those of lower density and the reverse flow at the surface (gradient flow). The velocity of the gradient flow must be proportional to the pressure drop, i. e. to the density gradient, which changes as the salinity gradient. It is obvious that the greater the L of the basin the lower is this velocity. Moreover, the velocity of the gradient flow is inversely proportional to the virtual viscosity (friction in turbulent flow [26]). In stratified water with density and salinity changing from layer to layer, this factor is much smaller than in homogeneous water. Therefore in a shallow basin where stratification is lacking because of mixing the velocity of gradient flow must decrease substantially as compared with the velocities of the gradient flow in deeper basins. Thus, the dependence of the gradient flow on the dimensions of the basin is the same as for turbulent diffusion.

A comparison of the character of all three processes leads to the conclusion that in relatively small evaporite basins the concentration of salts cannot reach values characteristic of halogenic zones without additional factors (for example the presence of shallows inhibiting gradient flow). On the other hand, in large basins in which compensation current is overwhelmingly important as compared with other

processes the appearance of halogenic zones is quite possible and regular.

It is very difficult to estimate to what extent drift currents inhibited the appearance and preservation of halogenic zones in evaporite basins. Here we cannot use the data on modern seas, for in the present geological period there are almost no very shallow basins of large area. Only some of the Arctic seas of the Soviet Union more or less approach this type of basin, but they have no large permanent currents [12].[6] All modern drift currents are in the oceans or deep seas, for evidently shallow depths prevent their formation. However, even if permanent drifts did exist in an evaporite basin, then, like the modern ocean currents, they would affect only a narrow belt.

According to oceanographic concepts [1, 26] in basins with depths less than 30 - 50 m, temporary variable drifts are not accompanied by opposite near-bottom currents. The wind action in such basins causes only temporary displacements of the entire thickness of water over an area in one direction or another. In an evaporite basin such currents would cause only brief periodic changes of the shape of the halogenic zone but would not remove its brine and freshen it.

In analyzing the unidirectional current in the evaporite basin we concluded that the halogenic zone will hug the shore with its belt of highest salinity against it (Figures 4 - 5). This will be so only if no fresh water is contributed from the land. Near river mouths a freshened zone will form in the littoral belt, its width depending on the amount of water delivered by the rivers.

It is natural that there should exist a transitional belt between the freshened and halogenic zones. Mainly by turbulent diffusion the salts characteristic of each of the two zones will be exchanged. The K, Na, Mg chlorides and Mg sulfates constituting the main part of dissolved salts will diffuse from the halogenic into the freshened zone (Table 1). Modern river waters are rich in calcium bicarbonate and carbonate, even oversaturated with these salts in arid regions [19], and it must be assumed that calcium carbonate and bicarbonate will diffuse from the freshened into the halogenic zone. The dominant precipitate near the halogenic zone enriched in the sulfate radical will be gypsum. Nearer to the shore, with the gradual disappearance of $MgSO_4$ and general freshening, the precipitation of gypsum will cease and dolomite will begin to form. The problem of carbonate parageneses has been fully analyzed in the well known work by N. M. Strakhov [17]. The separation of magnesium sulfate from the salt complex of the halogenic zone as a result of reaction with $CaCO_3$ must change the composition of its water.

After this theoretical discussion of the mechanism of brine formation in an evaporite basin, let us turn to the Lower Cambrian deposits of the Siberian platform and try to use this mechanism to explain some of the regularities in the distribution of their facies. The basic pattern (Figures 2 and 3) is a gradual transition from northeast and east to the south and southwest, from deposits of the zone of low salinity to deposits of the zone of high salinity.[7] As was shown above, during the entire Cambrian time there existed on the Siberian platform a single very shallow evaporite basin of vast area bounded on the south and west by continuous (Zhura time) or nearly continuous (Lena time) land masses. The direction of the compensation current can be perfectly definitely established by the paleogeographic setting. There is no doubt that the main mass of sea water of normal salinity was delivered to the Siberian platform from the northeast and partly from the east.[8] Thus, the conditions which existed during the Lower Cambrian were very similar to those in the basin with the unidirectional compensation current discussed above.

It is quite natural, therefore, that in the nearshore areas of the Lower Cambrian evaporite basin and in the areas far removed from the land and open towards the ocean there existed a halogenic zone attaining its greatest width in the farthest southwestern corner (as follows from equation [3]). As the cited data show, the greatest salt deposits actually lie in the inner part of the Irkutsk amphitheatre.

In the northwest, in the Turukhan region, the length of the compensation current was much less, the change in salinity sharper, and, as shown above, no halogenic zone could form. This explains the wedging out of the salt deposits from south to north along the western boundary of the Siberian platform (Figure 2).

The entry of streams from the land caused the appearance between shore and the halogenic

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[6]The reason for this is possibly the existence of extensive and long lived ice cover.

[7]The salinity gradients which it is possible to compute for the Lower Cambrian basin are quite commensurable with the theoretical ones (Table 2). Thus, on the northwest slope of the Aldan massif, where sections have been studied in detail, the salinity gradient within the transitional and high salinity zones is 500% $cm^{-1}.10^{-9}$, and in the outer part of the halogenic zone (the belt of deposition of sulfate-dolomite rocks) it is 1500% $cm^{-1}.10^{-9}$.

[8]It is probable that the territory of the modern marginal seas of the Arctic and Pacific oceans, the source of the compensation current, was occupied at that time by basins of other than evaporite type (either deeper basins or basins existing under different climatic conditions).

zone of a belt of water of high salinity and anomalous composition resulting from the mixing of fresh and salt waters. The addition of fresh water was apparently particularly large in the Yenisei region of the Lower Cambrian basin, as indicated by the abundance of terrigenous material in the Zhura and Lena deposits of this area, and for this reason the halogenic zone here lay farther from the shore.

These differences in the distribution of deposits of the zones of different salinity in the Lena stage as compared with the Zhura stage may be explained first of all by the increasing humidity of climate and also, probably, by the appearance of a connection between the Siberian platform basin and the southern geosynclinal sea. Thus the results of theoretical computations agree well with the actual geological facts and confirm our conclusion that in the Lower Cambrian evaporite basin salinity reached the stage of halite precipitation in a halogene zone which was not cut off or separated by bars from the rest of the sea.

This conclusion contradicts the widespread concept that salt deposits of marine origin can form only in lagoons, i. e. in basins barred from the sea or having only a very slight connection with it. This concept is based on modern cases and is actually confirmed by all observations on salt deposition of our time. However, the present geocratic period in the Earth's history substantially differs from many preceding periods, for now there are no broad epicontinental basins in the arid zone.

The idea that salt deposition requires areas cut off from the sea evidently arose from the analogy with modern lagoons and the assumption that the ancient saline basins were also supplied directly with marine water of normal or even low salinity (as, for example, Kara-Bogaz-Gol). The proximity of zones with such sharp difference in salinity that it can be attained only when 80% of the original volume has evaporated is, of course, impossible in a single basin.

In recent years a number of investigators have relinquished the classical concept of salt deposition. For example, M. P. Fiveg [21, 22], considering the well-known lack of correspondence found in many deposits between the composition of the rocks of the salt complex and the composition which should result from evaporation of sea water (for example low content of anhydrite), suggested that thick salt deposits were formed not in lagoons but in peculiar marine halogenic basins. These basins, as a rule, were not directly connected with the sea but communicated with it through intermediate basins..... " [21]. The sea water, flowing through this system of basins with an inhibited exchange of water, was gradually concentrated, and in the more distant, halogenic basins occupying areas of intensive subsidence thick salt beds were deposited from the more concentrated brines. Along the route of flow, in the intermediate basins, the less soluble salts were precipitated, such as carbonates and gypsum, while "the halogenic (halite) basins in which sea water was concentrated occupied only a small part of the total area of concentration" [21].

It is not difficult to see that Fiveg's hypothesis of formation of salt deposits accounts in a general way for the alternation of zones of different salinity observed by us in the Lower Cambrian deposits. However, to explain this process, Fiveg introduces essentially true lagoons, only arranging them in series. The formation of such a series is difficult to visualize, especially as the cause of isolation of the lagoons is explained by the author by the lowering of water level and shallowing of the basins due to intensive evaporation, an impossibility while there is a connection with the open sea.

N. M. Strakhov [18] in discussing the conditions of formation of dolomites arrives at the conclusion that in the extremely shallow Upper Paleozoic sea of the Russian platform lying in the semiarid climatic belt the salinity of the surface water in the pelagic zone was relatively high and hence dolomitic sediments were restricted to it. However, even assuming that salinity in some parts of the open sea was one and a half or two times greater than normal, Strakhov believes that the deposition of anhydrite required the formation of islands and shallows forming a maze in which "true lagoons almost completely isolated from the sea were formed from time to time."

Thus, admitting gradual increase in the concentration of salts in sea water before its arrival in the halogenic zone proper, both authors still consider it necessary to introduce barriers separating this zone from the open sea.

As was shown above (Table 2), the increase in salinity in an extensive evaporite basin must be very gradual, and this may be observed in some very shallow modern basins. For instance, in some of the areas of the Bahamas banks the salinity gradient reaches 102% $cm^{-1} \cdot 10^{-9}$. Within the shallow bays of the Caspian Sea, Mertvyy Kultuk and Kaydak, according to the data of 1934, the mean salinity gradient over a distance of 200 km was 191% $cm^{-1} \cdot 10^{-9}$. The most striking example is that of a branch of the Sivash, a single basin stretching for over 100 km from north to south. Here the average gradient is 1000% $cm^{-1} \cdot 10^{-9}$. These data confirm the possibility of the existence of zones of different salinity within a single basin.

Evidently the inception of evaporite basins with increasing salinity of the type described here was favored by the existence of arid climate over a large territory and by the first stages of a large transgression or the earliest stages of

slowly developing regressions, when extensive land areas of strongly peneplaned platforms were covered by shallow epicontinental seas.

It should be pointed out that the process of salt concentration in an evaporite basin suggested here makes precipitation of rock salt in an open marine basin possible but does not always lead to accumulation of large salt deposits. This requires an additional condition, namely, localization of the halogenic zone in an area of the earth's crust undergoing rapid subsidence. As we have seen, this favorable combination of conditions existed on the Siberian platform, where the largest salt deposits are restricted in time to the first half of the extensive Lower Cambrian transgression when the border of the platform adjacent to the mountains of the Baykal folded zone had a strong tendency to subside.

Evidently similar favorable conditions could have existed in the succeeding geological periods and similar regularities can probably be established for salt deposits of different ages. Undoubtedly sulfates and chlorides could have been deposited not only in extensive evaporite basins but also in typical lagoons similar to those existing now and forming most likely during the concluding stages of regressions.

In our opinion, the process of formation of salt deposits in evaporite basins explains certain structural peculiarities of salt deposits which which it is difficult to understand if the deposits are assumed to have formed in lagoons.

For example, it is difficult to imagine typical lagoons corresponding in size to the Verkhnekamsk deposit (225 km in length), the Permian basin of North America (1000 km long) and the Zeichstein basin of Europe extending for 1700 km [7].

Quite typical of evaporite basin deposits is the frequently observed persistence of salt beds along the strike. In the Verkhnekamsk deposit, for example, as pointed out by A. A. Ivanov [7], there existed "an amazing persistence and regional character of the conditions of sedimentation, so that over broad areas of the basin sediments of the same composition, of almost the same thickness and in the same sequence were deposited." Such persistence is hardly possible if it is assumed that deposition took place in numerous partly isolated lagoons lying in a maze of islands and shallows in a dessicating basin.

In all salt deposits there is alternation of rocks of different composition. Thus, halite alternates with anhydrite and potash salts with halite. "It is quite clear," writes A. A. Ivanov [7], "that without a periodic and rather copious addition of sea water to the basin (concentrated and with modified composition) diluting the brine of the basin, saturated with potassium and magnesium chlorides, and bringing in fresh portions of sodium chloride, such alternation in the composition of the crystallizing salts would be impossible." It is difficult to explain such frequent periodical invasions of sea water into lagoons, and it is hard to understand how this sea water became concentrated and changed in composition in advance. If the salts in an evaporite basin accumulated as described above, the intensity of evaporation would vary with climatic changes and thus changes in the composition of the chemical precipitates could occur without disturbing the general course of sedimentation.

REFERENCES

1. Berezkin, V. A., Dinamika morya. [DYNAMICS OF THE SEA]: Gidrometeoizdat, 1947.

2. Valyashko, M. G., Obyemnyye sootnosheniya zhidkikh i tverdykh faz v protsesse ispareniya okeanicheskoy vody kak faktor, opredelyayushchiy obrazovaniye mestorozhdeniy kaliynykh soley. [VOLUME RATIOS OF LIQUID AND SOLID PHASES AS FACTORS DETERMINING FORMATION OF POTASSIUM SALT DEPOSITS]: Doklady, Akademiya Nauk SSSR, t. 77, no. 6, 1951.

3. Geologiya i neftegazonosnost' Vostochnoy Sibiri. [GEOLOGY AND OIL AND GAS OCCURRENCES IN EASTERN SIBERIA]: Gostoptekhizdat, 1959.

4. Demokidov, K. K., O stratigraficheskom raschlenenii kembriyskikh otlozheniy severa Sibirskoy platformy. [ON STRATIGRAPHIC SUBDIVISION OF THE NORTHERN PART OF SIBERIAN PLATFORM]: Tr. N. -i. in-ta geol. Arktiki, t. 67, 1957.

5. Demokidov, K. K., N. Ye. Chernysheva, Ya. K. Pisarchik and O. I. Nekrasova, Stratigrafiya i fatsii kembriya Sibirskoy platformy. [CAMBRIAN STRATIGRAPHY AND FACIES OF THE SIBERIAN PLATFORM]: Tr. N. -i. in-ta geol. Arktiki, t. 80, 1958.

6. Zelenov, K. K., Litologiya nizhnekembriyskikh otlozheniy severnogo sklona Aldanskogo massiva. [LITHOLOGY OF THE LOWER CAMBRIAN ROCKS OF THE NORTHERN SLOPE OF THE ALDAN MASSIF]: Tr. geol. in-ta Akad. Nauk SSSR, vyp. 8, 1957.

7. Ivanov, A. A., Osnovy geologii i metodika poiskov, razvedki i otsenki mestorozhdeniy mineral'nykh soley. [FUNDAMENTALS OF GEOLOGY AND THE METHODS OF EXPLORATION AND EVALUATION OF SALT DEPOSITS]: Gosgeolizdat, 1953.

8. Levich, V. G., Fiziko-khimicheskaya gidrodinamika. [PHYSICOCHEMICAL HYDRODYNAMICS]: Izd. Akad. Nauk SSSR, 1952.

9. Lermontova, Ye. V., Nizhnekembriyskiye trilobity i brakhiopody Vostochnoy Sibiri. [LOWER CAMBRIAN TRILOBITES AND BRACHIOPODS OF EASTERN SIBERIA]: Gosgeolizdat, 1951.

10. Lineykin, P. S., Ob izmenenii solenosti poverkhnostnogo sloya morya pri vypadenii osadkov. [ON THE CHANGE IN SALINITY OF THE UPPER WATERS OF THE SEA DUE TO PRECIPITATION]: Izvestiya, Akad. Nauk SSSR, ser. geofiz., no. 2, 1953.

11. Mezhvilk, A. A., Stratigrafiya Severnogo Kharaulakha. [STRATIGRAPHY OF NORTHERN KHARAULAKH]: Sov. geologiya, no. 7, 1958.

12. Morskoy atlas t. 1. [MARINE ATLAS V. 1]: Izd. Morskogo gen. shtaba, 1950.

13. Pokrovskaya, N. V., Stratigrafiya kembriyskikh otlozheniy yuga Sibirskoy platformy. [CAMBRIAN STRATIGRAPHY OF THE SOUTH OF THE SIBERIAN PLATFORM]: Vopr. geol. Azii, t. 1, 1954.

14. Repina, L. N., Paleontologicheskoye obosnovaniye vozrasta otlozheniy kembriya zapadnoy chasti Vostochnogo Sayana. [PALEONTOLOGICAL EVIDENCE FOR THE CAMBRIAN AGE OF THE DEPOSITS IN THE EASTERN PART OF SAYAN MOUNTAINS]: Doklady, Akad. Nauk SSSR, t. 110, no. 2, 1956.

15. Savitskiy, V. Ye., O stroyenii i ob"yeme Aldanskogo yarusa kembriya na severe Sibirskoy platformy. [ON THE STRUCTURE AND CONTENT OF THE CAMBRIAN ALDAN STAGE IN THE NORTH OF THE SIBERIAN PLATFORM]: Inform. byull. N. -i. in-ta geol. Arktiki, vyp. 1, 1957.

16. Semikhatov, M. A., Nizhniy kembriy Kansko-Angarskoy vpadiny. [LOWER CAMBRIAN OF THE KAN-ANGARA BASIN]: Byul. Mosk. o-va ispyt. prirody, otd. geol., t. 34, vyp. 2, 1959.

17. Strakhov, N. M., Izvestkovo-dolomitovyye fatsii sovremennykh i drevnikh vodoyemov. [LIMESTONE AND DOLOMITE FACIES OF MODERN AND ANCIENT BASINS]: Tr. In-ta geol. nauk, vyp. 124, no. 45, 1951.

18. Strakhov, N. M., O tipakh i genezise dolomitovykh porod. [ON TYPES AND GENESIS OF DOLOMITIC ROCKS]: Tr. geol. in-ta AN SSSR, vyp. 4, 1956.

19. Strakhov, N. M., et al., Obrazovaniye osadkov v sovremennykh vodoyemakh. [DEPOSITION OF SEDIMENTS IN MODERN BASINS]: Izd. Akad. Nauk SSSR, 1954.

20. Suvorova, N. P., O lenskom yaruse nizhnego kembriya Yakutii. [ON THE LOWER CAMBRIAN LENA STAGE OF YAKUTIYA]: Vopr, geol. Azii, t. 1, 1954.

21. Fiveg, M. P., Geologicheskaya obstanovka sedimentatsionnogo etapa obrazovaniya solenosnykh formatsiy. [GEOLOGICAL ENVIRONMENT OF FORMATION OF SALT-BEARING DEPOSITS]: Vopr. mineralogii osad. obrazovaniy, kn. 3-4. L'vov, 1956.

22. Fiveg, M. P., Tipy solerodnykh basseynov. [TYPES OF SALINE BASINS]: Tr. Vses. n. -i. in-ta galurgii, vyp. 32, 1956.

23. Khomentovskiy, V. V., K tektonike Vostochnogo Sayana. [TECTONICS OF EASTERN SAYAN]: Izvestiya, Akad. Nauk SSSR, ser. geol., no. 7, 1957.

24. Chernysheva, N. Ye., Stratigrafiya kembriyskikh otlozheniy yugo-vostochnoy okrainy Sibirskoy platformy. [STRATIGRAPHY OF CAMBRIAN DEPOSITS OF THE EASTERN MARGIN OF SIBERIAN PLATFORM]: Materialy Vses. n. -i. in-ta, vyp. 7, 1955.

25. Chernysheva, N. Ye., K voprosu o raschlenenii kembriyskikh otlozheniy Sibirskoy platformy. [ON SUBDIVISION OF THE CAMBRIAN DEPOSITS OF SIBERIAN PLATFORM]: Sov. geologiya, no. 55, 1957.

26. Shuleykin, V. V., Fizika morya. [PHYSICS OF THE SEA]: Izd. Akad. Nauk SSSR, 1953.

27. Krumbein, W. C., Occurence and lithologic associations of evaporites in the United States. J. Sediment. Petrol., vol. 21, no. 2, 1951.

28. Sloss, L. L., The significance of evaporites. J. Sediment. Petrol., vol. 23, no. 2, 1953.

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ON SOME CRITERIA OF THE PRIMARY OR SECONDARY NATURE OF BITUMENS[1]

by

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The question whether deposits of petroleum and bitumens are primary or secondary has great theoretical and practical importance. A definite answer to this question in every concrete case can throw light on the origin of petroleum, help to elucidate the laws of its migration and broaden existing knowledge of the formation of economic deposits.

As has been shown by V. M. Strakhov [16], organic matter plays an important part in diagenetic processes, and the regularities of its distribution often determine the areal distribution of certain sedimentary rocks. The distinction between authigenic and allogenic organic matter must be regarded as one of the urgent problems of theoretical lithology.

Moreover, economic concentrations of some minor, trace and radioactive elements are connected with organic matter. For example, according to A. F. Dobryanskiy [8], R. Erickson, Myers and Horr [29] and others, the oil refineries of the U. S. A. have taken out patents on economic utilization of vanadium contained in the ash of bituminous sands. Gott and Erickson [30], Breger and Deuel [4] and others have discussed the genetic relation between petroleum bitumens and sedimentary deposits of uranium. Krauskopf [32] noted high rare earth content in petroleum and asphaltum ash, and other investigators have detected selenium in bituminous shales, sandstones and limestones [15]. Evidently the origin, the character of occurrence and the prospecting clues to economic concentrations of petroleum and its derivatives depend to a considerable extent on whether the organic matter itself is primary or secondary.

The work of I. M. Gubkin [7], A. D. Arkhangel'skiy [1] and others has shown that the problem of determining whether organic matter is primary or secondary requires a complex approach. The pioneers in petroleum geology, in studying the problem of the migration of petroleum, used all available methods of investigation of organic matter and enclosing rocks, and did not rely on the results obtained by a single method. A good example of this is the work of Arkhangel'skiy, "The conditions of formation of petroleum in the northern Caucasus" [1], in which the Tertiary deposits of the Grozny oil field, containing authigenic petroleum, were studied by the methods of comparative lithology, tectonics, stratigraphy and geochemistry.

Later, thanks to the investigations of V. B. Tatarskiy [18, 19, 20], petrographic study of organic matter came into general use. The mutual relationship between bitumens and various components of the enclosing rock as observed in thin sections was the cornerstone of these investigations. A study of the characteristics of petroleum-bearing carbonate rocks of Middle Asia was used to formulate definite criteria which became generally accepted for determining the primary or secondary nature of organic matter in petroleum.

The simplicity and availability of the petrographic method of study, the popularity of Tatarskiy's works and the attractive definiteness of the answer to the question whether a given bitumen is authigenic or allogenic, obtained by means of a microscope, made some authors discard the complex method of investigation and accept the petrographic method in preference to all others.

However, in many cases Tatarskiy's petrographic criteria [19] cannot definitely distinguish between authigenic and allogenic bitumens, and it always requires additional checking by other methods. This became clear to the present author after lithological studies of the principal oil-bearing horizons of Middle Asia.

Bitumens in Oolites

Oolitic limestones and dolomites are widespread among the Paleogene carbonate rocks

[1] O nekotorykh kriteriyakh pervichnosti ili vtorichnosti bitumov.

of the Fergana valley. Under the microscope, calcareous oolites appear as small round bodies 1 to 2 mm in diameter. Very often, but not always, a fragment of a foraminifer shell, a quartz grain or some other particle lies at the center of an oolite. The outer part of an oolite usually consists of a series of concentric spherical shells with radiated structure. Less common are complex oolites composed of several small ones lying close together and enveloped in a common concentric shell with radiated structure.

In some parts of a bed oolites may be cut by numerous cracks filled with crystalline calcite or bitumen. Sometimes bitumen fills entire concentric zones in the oolites, but in such cases it is always connected by a channel with the surrounding matrix, which also carries yellowish-brown segregations of bitumen.

Sometimes well preserved oolites are found containing clay, pyrite and marcasite intimately associated with bitumen in the concentric shells. It is clear that according to the mode of occurrence of bitumen in them oolites may be placed in two large groups.

The first group includes strongly deformed oolites with radial fractures containing obviously secondary bitumens which penetrated into these calcareous bodies at a late stage in the history of the sedimentary rock.

To the second group belong well preserved oolites containing bitumen between the concentric shells. It is this mode of occurrence of bitumen that was regarded by Tatarskiy [19, 20] as a proof of its syngenetic origin.

It should be pointed out, however, that a detailed study of the processes occurring in the beds of oolitic rocks makes this very definite conclusion doubtful. The idea that the bitumen included between the concentric shells of an oolite is syngenetic is based on the assumption that the outer shells of oolites have low permeability.

It appears, however, that the outer shells of oolites do not always prevent penetration of solutions into the interior. This becomes apparent after a study of metasomatic replacement of oolites by silica.

A photomicrograph of well preserved oolites replaced by silica is shown in Figure 1. Quartz, sometimes in euhedral hexagonal crystals 0.05 mm in diameter, can be seen between the concentric shells. At high magnifications these quartz crystals reveal relicts of concentric shells composed of radiated calcite, and one gets the impression that quartz crystals grew through the inner shells of the oolites.

In Figure 2 quartz replaces a gastropod shell forming the nucleus of an oolite. Here again outlines of large quartz crystals growing through radiated calcite are visible among the concentric shells.

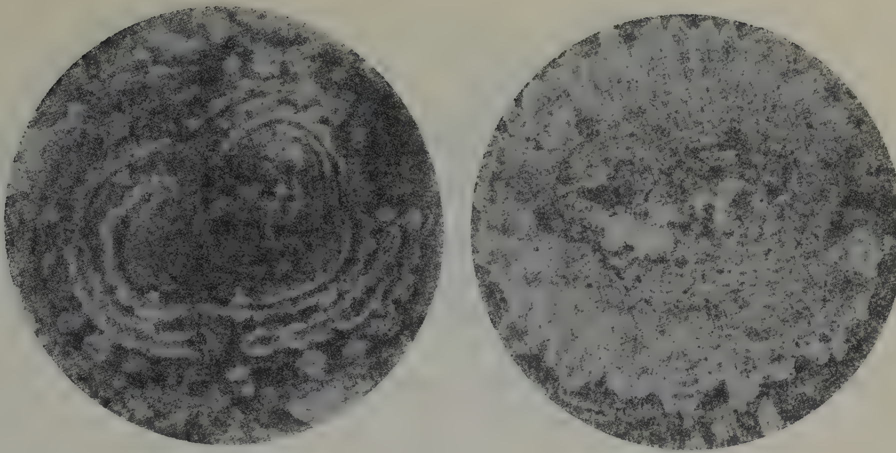
It is interesting to note that in these cases there are no traces of channels or craks by which silica solutions could have penetrated into the oolites. Usually the oolites are very well preserved.

On the other hand, the presence of relict radiated calcite within the secondary quartz, the frequent cases of replacement of the calcite cement by quartz in the same specimens and, even more, the frequent silicification of the shells of gastropods, foraminifera and pelecypods or their fragments, and, finally, the shape of siliceous concretions and their relationships with the enclosing rocks, convince us that all this is the result of metasomatic replacement of calcite by silica brought in by waters circulating in the calcareous ooze or in the rock while it was forming.

Evidently in spite of the absence of visible channels by which silica-bearing solutions could reach the interiors of oolites the outer shells were sufficiently permeable to let the solutions pass and the inner shells became the scene of subtle metasomatic phenomena. Very interesting in this connection are the data given by Henbest [31]. This author described peculiar oolites in the Pennsylvanian carbonate rocks of Arkansas. Here, large well preserved oolites with quartz nuclei are common and the quartz fragments are usually euhedral and show no signs of abrasion. An investigation of these quartz nuclei showed that they consist of two parts. The inner part is irregular and is probably a detrital quartz grain which served as the nucleus for the growth of the oolite. The outer part, on the other hand, has crystal outlines and contains numerous inclusions of radiated calcite evidently representing relicts of the inner oolite shells replaced by quartz growing on the detrital grain.

The author explains this phenomenon in the following way (Figure 3). First the concentric shells of the oolite developed sround the detrital quartz grain in the usual way (Figure 3, I) and the oolite was formed. Later, silica-bearing solutions began to seep into the calcareous structure (Figure 3, II), and the detrital grain was regenerated into a quartz crystal in perfect accordance with the optical orientation of the grain. As the quartz crystal grew, the inner calcareous shells were dissolved, but a few fragments of the dissolving shells were captured by the outer zones of growing quartz crystal as shown in Figure 3, III.

The case described by Henbest is evidently a variant of silica metasomatism. It is especially interesting because of the increase in the



a b

FIGURE 1. Calcareous oolites with crystals of secondary quartz in the concentric shells.

a - sp. 41, x 46; b - sp. 51, x 90. Dark areas - radiated calcite in the oolite shells, white - quartz.

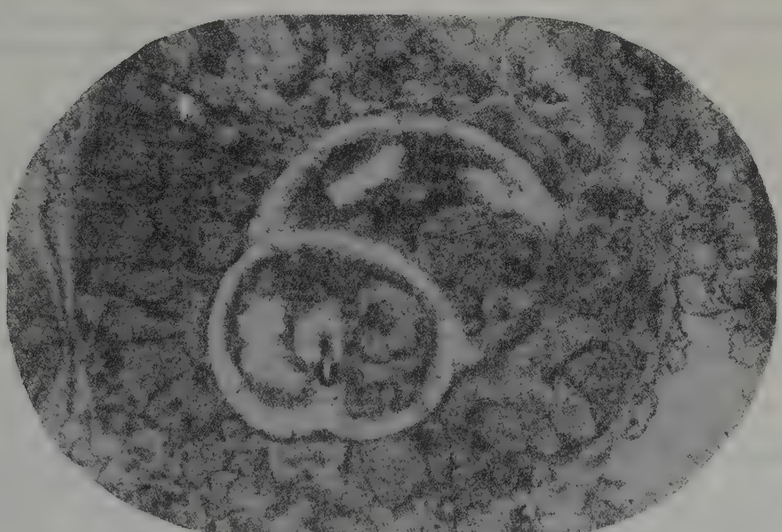


FIGURE 2. Gastropod shell filled with quartz forming nucleus of an oolite.

Sp. 424-11, x 90. Secondary quartz has grown through the outer oolite shell. Dark-calcite, white-quartz.

volume of the quartz nucleus, which could not have occurred without introduction of additional silica into the interior of the oolite.

On the other hand, the good preservation of the calcareous shells adjacent to the quartz crystal points to their solution rather than mechanical destruction by the growing crystal.

In any case, it may be considered as established that silica-bearing solutions penetrate into oolites which have no visible radial cracks.

It should be added that this phenomenon is not limited to silica solutions and that magnesium metasomatism leading to the replacement of calcitic oolites by crystallized dolomite is accomplished in the same way. Cases of

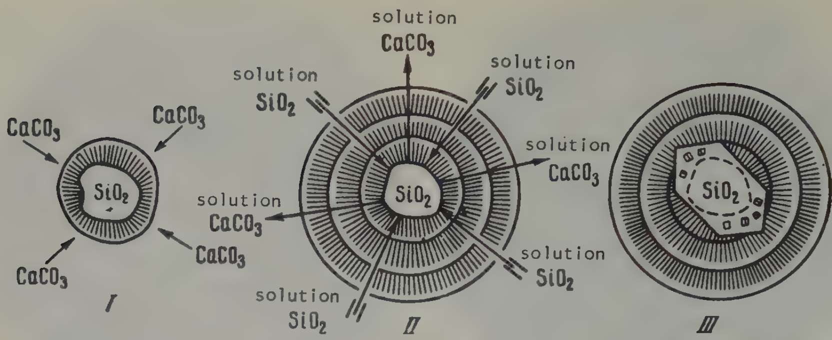


FIGURE 3. Diagram showing formation of quartz crystals at the center of an oolite (V.N. Kholodov after L. Henbest).

formation of metasomatic dolomite have already been described from the Paleogene of Middle Asia by A.I. Osipova [13] and from the carbonate rocks of other regions, by B.P. Krotov [9], G.I. Teodorovich [21] and others.

The author observed this phenomenon in the carbonate rocks of the Fergana valley. Here, besides the usual oolites with concentric-radiated structure, oolites with clotted or spotted structure were found.

The microscope shows that the spotted structure of these oolites is due to the penetration of the radiated calcite by rhombohedral crystals of dolomite. Morphologically this phenomenon is very similar to the process of silicification described above (Figure 1), for most frequently dolomitization takes place along the concentric shells of an oolite and in the early stages of the process only the outlines of dolomite crystals enclosing radiated calcite are to be seen (Figure 4, a).

It should be emphasized that this type of replacement is characteristic of rocks containing small amounts of dolomite. When dolomite content is high, the oolites lose their radiated structure completely and are transformed into structureless clots in which concentric chains of dolomite crystals lie in a matrix of coarsely crystallized calcite (Figure 4, b).

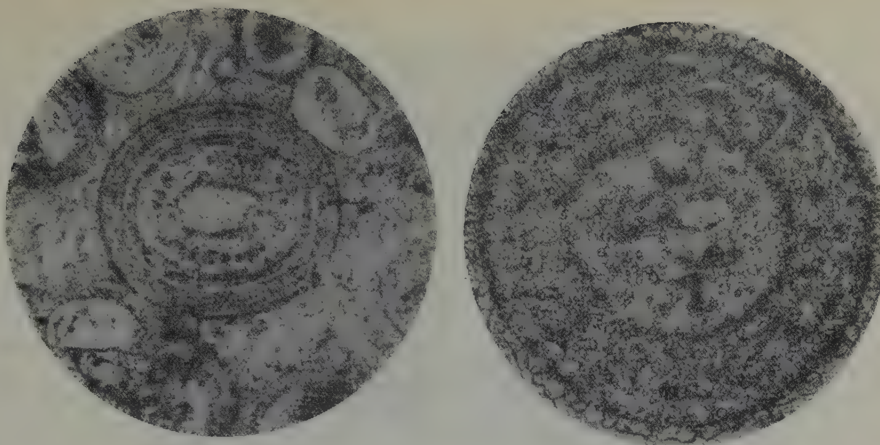
Two points should be noted in connection with the dolomitization of oolites. First, it appears evident that the process of replacement is always secondary with respect to the oolites, whether it occurred during diagenesis or epigenesis. Second, microscopic investigation shows that the replacement of oolites from within occurs even when the outer shells do not exhibit visible cracks or other channels providing for the entry of solutions. This suggests that the entire outer surface of an oolite is covered with a network of capillary cracks allowing easy penetration of solutions.

The idea of considerable permeability of the outer concentric shells of oolites is confirmed by the observations on the destruction and leaching of carbonate rocks near the surface or in zones of intensive circulation of ground water. Under these conditions it is the oolites that first succemb to the action of water: their inner shells are dissolved and cavities are formed. These cavities are often filled with coarsely crystalline gypsum, calcite or some other secondary mineral.

An attempt was made to check experimentally the possibility of concentration of secondary bitumens in calcareous oolites. A specimen of coarsely oolitic limestone was placed in a vessel with viscous petroleum and kept in it for 26 days. The rock was then taken out of the vessel and sectioned. In order to preserve the organic matter, thin sections were prepared without heating. Samples of the rock before and after the experiment are shown in Figure 5. Microscopic examination shows that petroleum easily penetrates not only the broken but also the whole oolites and is not concentrated in the matrix of the rock. Moreover, secondary bitumen is very irregularly distributed within the concentric shells, selectively saturating some of them and the shells of foraminifera at the center.

Thus, the high permeability of the outer shells of oolites indicates that the bitumen found within undeformed oolites cannot always be considered syngenetic. In deciding whether the bitumen is primary or secondary, it is absolutely necessary to take into account the position of the bitumen in the geological section and in the region. This will be illustrated by an example.

The Mayli-Say ozocreite deposit in the Fergana valley has been repeatedly mentioned in the geological literature [10, 11 and others]. A considerable part of the ozocerite in this deposit is related to carbonate rocks of horizon "m" of the Paleogene Turkestan stage. Locally,



a б

FIGURE 4. Calcareous oolites with crystals of secondary replacing concentric shells.

a - sp. 290, x 46. A well preserved oolite with crystals of dolomite grown in it; b - sp. 215. Oolite completely replaced by dolomite crystals.

the ozocerite fills large fractures in the bed, but its main mass occurs in the carbonate rocks in the pores, in the cavities of calcareous shells and in the shells of well preserved oolites. In thin sections prepared without heating, the oolites are dark brown, because of the presence of ozocerite, and stand out sharply against the groundmass of coarsely crystalline calcite cement.

It has been made clear already that it is difficult to decide definitely on the basis of petrographic study alone whether the ozocerite is primary or secondary. To answer this question it is necessary to examine the position of the ozocerite deposit in the section and in the region. Within the area ozocerite occurs fairly persistently in horizon "m" of the Turkestan stage, while the argillaceous rocks underlying and overlying the carbonate rocks are free of it.

The ozocerite-bearing Turkestan limestones are folded into a small anticline striking approximately due east. Near the top of the fold, horizon "m" is exposed in a north trending gully and the ozocerite deposit is located in its western bank (Figure 6).

The intimate relation between the ozocerite deposit and the outcrop of carbonate rocks attracts attention, for the deposit wedges out down dip, away from the surface. Locally the boundaries of the deposit intersect contours of the top of the carbonate bed. Litholfacies studies show that this attitude of the deposit bears no relation to the facies changes in bed "m". It is noteworthy that the carbonate oolites beyond the boundary of the deposit are practically devoid of bitumen and, as shown by thin sections, almost merge into the matrix of the rock.

These features of the distribution of ozocerite indicate that the deposit as a whole is secondary and was formed in rocks which had undergone folding and erosion. This conclusion is fully in accord with the ideas of V. N. Muratov [11] and other investigators of the Fergana ozocerite deposits.

As for the ozocerite included in calcareous oolites, it should also be viewed in the light of the formation of the deposit as a whole and regarded as allogenic.

Bitumens in Dolomites and Dolomitic Rocks

The Paleogene dolomites of Fergana often contain individual beds and spotted or spotted-banded areas of rock containing a considerable amount of petroleum bitumens which color them yellowish-brown or brown.

Microscopic examination of such areas shows that the organic material is concentrated in the interstitial spaces among rhombohedral dolomite crystals. These crystals are sometimes zoned and their inner zones are filled with calcite, also containing bitumen. The outer rhombic dolomite zones are usually free of all foreign inclusions.

The mode of occurrence of bitumens similar to that just described is regarded by V. B. Tatarskiy [18] as indicating that the organic matter is syngenetic, and his conclusion has been

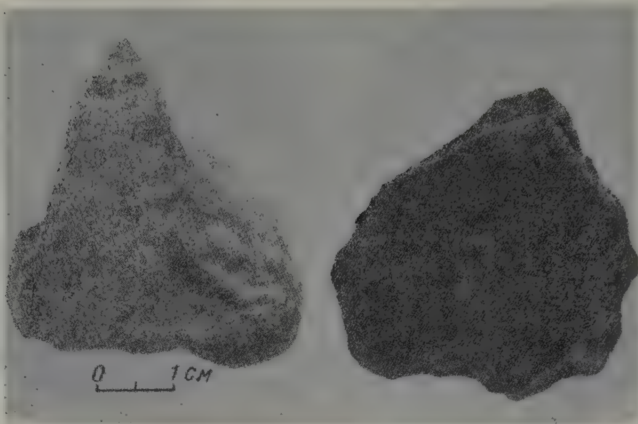


FIGURE 5, I. Photographs of a fresh fragment of oolitic limestone before and after saturation with viscous petroleum.

repeated without comment in the works of a number of authors, for example in the paper by Yu. A. Khodak [24].

Turning to the discussion of the origin of the bitumen accumulation in dolomites, it should be noted that Khodak's statement [24] that the determining role in their formation was played by the crystallization of $CaMg(CO_3)_2$ is probably correct. The growing dolomite crystals could have "cleared themselves" of impurities and caused transfer of organic material to the peripheries of the rhombohedra and simultaneous growth of several crystals could have forced the bitumen into interstitial spaces and produced the above described occurrence. This hypothesis of crystallization is confirmed by Tatarskiy's observations [18], which prove that the bitumen interstitial to dolomite crystals is "strongly held by the rock and can be displaced only by drastic treatment."

This hypothesis leads to the following conclusions:

1. The bitumen (or the organic matter which served as its source) was present in the mud or rock before the crystallization of dolomite.

2. The accumulations of bitumen "squeezed" between the dolomite rhombohedra occurred synchronously with the crystallization of $CaMg(CO_3)_2$.

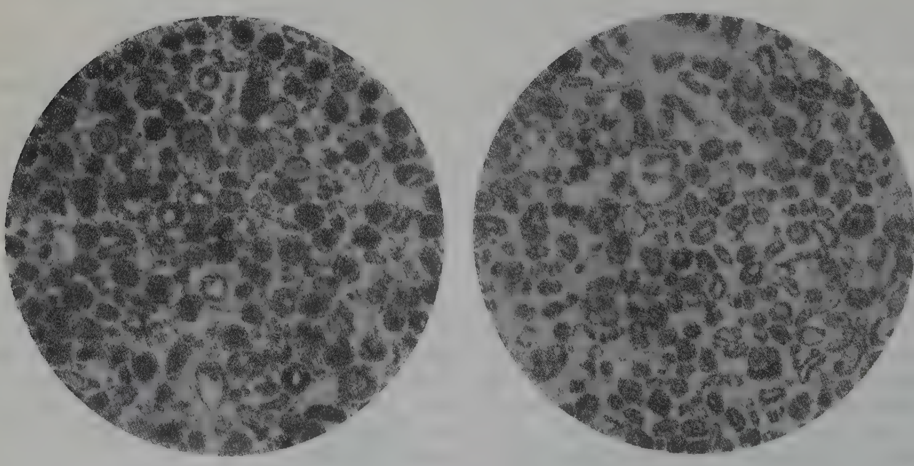


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FIGURE 5, II. a - photomicrograph of oolitic limestone before experiment; b - photomicrograph of the same rock saturated with petroleum x 6.

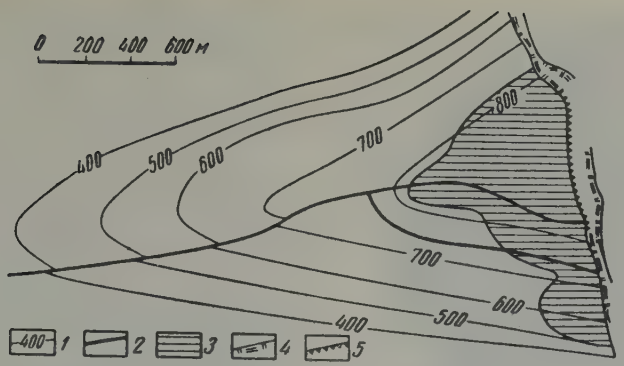

FIGURE 6. Sketch map on top of zone "m" of the Maylisay ozocerite deposit.

1 - contours on top of horizon, 2 - fault, 3 - ozocerite deposit, 4 - bank of gully, 5 - outcrop of the zone.

It becomes evident that to interpret the mode of occurrence of bitumen it is necessary, first, to establish the origin of the dolomitic rocks and, second, to date rather definitely the time of formation of dolomite crystals.

Both here and abroad there is a vast literature devoted to the origin of dolomites. Among the multitude of hypotheses proposed to explain the process of dolomitization, two points of view may be readily distinguished.

One group of investigators [14, 17, 20, 21, 23] considers that most dolomites are formed during sedimentation and diagenesis. The role of epigenetic dolomitization is reduced to a minimum by them and they believe that dolomite very seldom crystallizes in the already lithified sediments.

The opposite view of the formation of dolomite has been presented in the works of M. E. Noinskiy [12], Z. A. Bogdanova [3], S. G. Vishnyakov, T. P. Afanas'yev [2] and others. These investigators admit the possibility of the formation of great thicknesses of dolomite and dolomitized rocks as a result of the circulation of ground waters through previously deposited carbonate rocks, but believe also that dolomites may form as a result of direct precipitation of $CaMg(CO_3)_2$ from sea water (sedimentary or primary dolomites) and during the ooze stage in the development of a carbonate rock (diagenetic dolomites).

The mode of occurrence of dolomite is used as a criterion for distinguishing sedimentary, sedimentary-diagenetic and epigenetic dolomites. Strakhov [17] states, "The bedded Paleozoic dolomites are primary or sedimentary; the spotted metasomatic dolomites are sedimentary-diagenetic; and dolomites filling cracks, pores and caverns in pre-existing rocks are epigenetic" (p. 23). S. G. Vishnyakov [5] asserts that besides forming beds, sedimentary (and diagenetic) dolomites occur in lenses. The epigenetic dolomites, according to this author, form very intricate bodies very often transgressing stratigraphic boundaries. T. P. Afanas'yev [2] has shown that the spatial position of epigenetic dolomites is intimately connected with the water table and the structure of the region. In most cases, intensive dolomitization occurs near the crests of anticlines.

Thus, before it is possible to say whether the bitumens are primary or secondary it is necessary to study the spatial position of dolomites thoroughly by means of lithofacies and sometimes tectofacies analysis.

If it is established for a given region that the dolomite is epigenetic, the question whether the associated organic matter is authigenic or allogenic becomes rather indefinite. The work of A. I. Gorskaya [6], P. V. Smith [33] and others has shown that liquid hydrocarbons are present in the modern muds of the Caspian sea and the Gulf of Mexico. This evidently indicates that petroleum may migrate through bottom muds. The migration of petroleum bitumens through lithified carbonate rocks is now taken for granted. Therefore, migration of hydrocarbons is possible during both diagenesis and epigenesis, and the formation of epigenetic dolomite crystals undoubtedly may cause fixation of introduced organic matter.

As for the association of allogenic bitumen with epigenetic dolomite, examples can be cited based on the investigation of the carbonate rocks of the Tamda formation in the Malyy Karatau

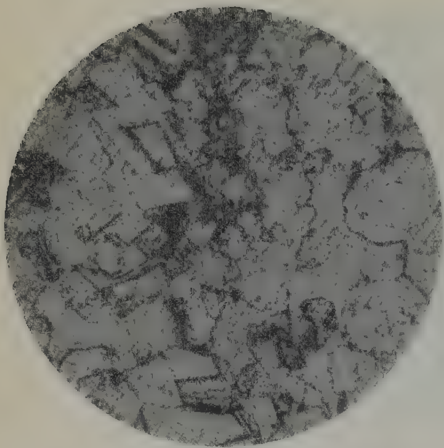

FIGURE 7. Zoned crystals of dolomite with included bitumen (dark) fill a fracture. Sp. 969, x 21.

region. Here, thin cracks filled with zoned dolomite crystals are rather common in the beds of crystalline limestone (Figure 7). The epigenetic origin of the dolomite is unquestionable, because it occurs predominantly in the fractures. The inner zones of the dolomite rhombohedra and the spaces between crystals are often filled with brownish-yellow bitumen. Evidently the bitumen was trapped in the dolomite crystals when they were forming and its presence in the cracks is most correctly explained by migration of hydrocarbons.

The case illustrated by Figure 7 is interesting also because it proves that zoned crystals of dolomite may form during epigenesis.

When dolomite is formed by the sedimentary and diagenetic processes the probability that the bitumens present in it are primary is somewhat higher. Inasmuch as many bituminous dolomites of Fergana are of this type, this question will be discussed in some detail.

A tectofacies analysis of the Paleogene carbonate rocks of the Alay stage in the Fergana basin was made by the author. The method of analysis and a detailed description of the investigation were given in a series of papers [26, 27, 28].

It was shown that the average dolomite content in the sections of the carbonate horizon "l_1" varies areally in perfect correspondence to the variation in the thickness of the beds and that the thickness of the beds reflects the present structure of the region. The resemblance between the distribution of the insoluble residues and of $CaMg(CO_3)_2$, together with the regular relationship between bed thickness and dolomite content in the rocks, leads to the conclusion that the main mass of magnesium was introduced into the mud of the ancient basin synchronously with the accumulation of calcium carbonate and probably has not been redistributed since then.

The Alay dolomites occur mostly in tabular or lens-like bodies. When the dolomite sequences are thick, lenses become beds and extend over great distances.

Microscopic investigation shows that pure dolomites are composed of masses of small rhombohedral crystals containing inclusions of calcitic oolites and fossil fragments. Numerous relict structures are present in the dolomitic limestones. Most frequently they are relicts of oolitic and organic limestones with calcareous oolites and fossil fragments replaced by zoned dolomite crystals.

That dolomite is secondary after calcite is proved by the close relation between the degree of dolomitization of the rocks and the distribution of relict structures, the frequent replacement of calcitic oolites and fossils by dolomite and, finally, by overgrowths of dolomite on calcite and diagenetic pyrite.

Thus the formation of dolomites and dolomitic rocks in the Alay deposits is clearly divisible into three stages:

1. The separate precipitation of calcium carbonate and magnesium compounds from the waters of the ancient basin. Some of the $CaCO_3$ was undoubtedly precipitated by organisms and is represented by the shells of gastropods, pelecypods, foraminifera and oysters and by shell detritus. The precipitated magnesium compounds enriched the deeper areas of the basin floor and formed close association with clays.

2. The crystallization of chemically precipitated $CaCO_3$ and probably the formation of oolites in the calcareous mud [16].

3. The replacement of calcitic fossils and oolites by dolomite and the formation of zoned crystals of $CaMg(CO_3)_2$, mainly in the muds of the ancient basin.

Evidently in their mode of occurrence these rocks are nearest of all to the sedimentary-diagenetic dolomites of Strakhov [17].

It may appear that the petroleum in dolomitic rocks formed from the bottom muds may be regarded as authigenic, but this is not quite so. The fact is that there are no reasons to limit crystallization of dolomite to the diagenetic stage. On the contrary, in some areas rhombohedra of dolomite "heal" secondary calcite veinlets; elsewhere they envelop epigenetic

pyrite and marcasite and sometime displace and "pull apart" thin stylolitic seams which, as was shown earlier [25], form during epigenesis.

Thus, a part of the dolomite crystals, a small part perhaps, was undoubtedly formed after diagenesis in an already lithified sediment. There are reasons to believe that on the whole crystallization and recrystallization of dolomite are not accompanied by significant migration of magnesium compounds within the bed, but even local regrouping of material could cause "capture" of migrating petroleum by the growing crystals. And it is precisely in this way that some interstitial accumulations of bitumen resistant to destruction and weathering could have formed among dolomite crystals in the Paleogene rocks of Fergana.

Thus, the sedimentary-diagenetic dolomites may accumulate both authigenic and allogenic organic matter. The quantitative relationship between these two groups of bitumens is not clear, but it is probable that authigenic bitumens predominate.

As for the sedimentary dolomites containing organic matter of the petroleum series in the spaces among the dolomite rhombohedra $CaMg(Co_3)_2$, they offer even better possibilities for preservation of primary organic matter, and if the little known processes of epigenetic recrystallization are ignored, Tatarskiy's ideas [18] may be applicable to them.

SUMMARY

Petrographical criteria of the primary or secondary nature of bitumens, when used alone without being checked by geological methods of investigation, do not, as a rule, justify themselves.

For example, because of the permeability of oolites, the bitumen occurring among their concentric shells may be regarded either as introduced into an already formed oolite or as authigenic, formed at the time of growth of calcareous shells. Study of the distribution of bitumen-bearing oolites in the section and throughout an area gives a more definite answer to the question of the primary or secondary nature of organic matter in the oolites.

The more complex case of preservation of bitumens in the interstices among the dolomite crystals must also be studied by the combined m methods of petrography and geology. A partial solution of the problem of the primary or secondary nature of bitumens is possible by a study of the mode of occurrence of bituminous dolomites and of their position in space, which throws light on the origin of the rocks and also by lithological and petrographic investigations directed to the determination of the time of crystallization of dolomite. It must be admitted, however, that even such laborious investigations cannot give a unique answer to the question whether the organic matter in dolomites is primary or secondary. It is possible that a complete solution of the problem requires, in addition, geochemical investigation of the organic matter.

REFERENCES

1. Arkhangel'skiy, A.D., Usloviya obrazovaniya nefti na Severnom Kavkaze. [CONDITIONS OF FORMATION OF PETROLEUM IN NORTHERN CAUCASUS]: Moscow-Leningrad, 1927.

2. Afanas'yev, T.P., O roli podzemnykh vod v dolomitizatsii porod. [THE ROLE OF UNDERGROUND WATER IN DOLOMITIZATION]: Doklady, Akad. Nauk SSSR, 62, no. 4, 1948.

3. Bogdanova, Z.A., K litologii karbonatnykh porod nizhnego karbona Podmoskovnogo basseyna. V kn. Litolog. sb. pamyati prof. S.F., Malyavkina, vyp. 1. [LITHOLOGY OF THE LOWER CARBONIFEROUS ROCKS OF THE MOSCOW BASIN. IN THE BOOK: LITHOLOGICAL COLLECTION IN MEMORY OF PROF. S.F. MALYAVKIN, VYP. 1]: Gosgeolizdat, 1940.

4. Breger, I.A. and M. D'yul, Organicheskaya geokhimiya urana. V sb. Geol. Atomn. Syr'yevykh Materialov. [ORGANIC GEOCHEMISTRY OF URANIUM. IN THE BOOK: GEOLOGY OF ATOMIC RAW MATERIALS]: GONTI, 1956.

5. Vishnyakov, S.G., Geneticheskiye tipy dolomitovykh porod severo-zapadnoy okrainy Russkoy platformy. [GENETIC TYPES OF DOLOMITIC ROCKS ON THE NORTHWESTERN BORDER OF THE RUSSIAN PLATFORM]: Tr. geol. in-ta Akad. Nauk SSSR, vyp. 4, 1956.

6. Gorskaya, A.I., Izucheniye organicheskogo veshchestva sovremennykh morskikh osadkov. V sb. Nakopl. I Preobr. Organich. Veshchestva v Sovrem. Morskikh Vodoyemakh. [A STUDY OF ORGANIC MATERIAL IN MODERN MARINE SEDIMENTS. IN THE BOOK: ACCUMULATION AND TRANSFORMATION OF ORGANIC MATTER IN MODERN MARINE BASINS]: Moscow, 1956.

7. Gubkin, I.M., Izbrannyye sochineniya, t. 1, 2. [SELECTED WORKS, V. 1, 2]: Izd. Akad. Nauk SSSR, 1950-1953.

8. Dobryanskiy, A.F., Geokhimiya nefti. [GEOCHEMISTRY OF PETROLEUM]: Gostoptekhizdat, 1948.

9. Krotov, B.P., Dolomity, ikh obrazovaniye, usloviya ustoychivosti v zemnoy kore i izmeneniya v svyazi s izucheniyem dolomitov verkhnikh gorizontov kazanskogo yarusa v okrestnostyakh g. Kazani. [DOLOMITES, THEIR FORMATION, CONDITIONS OF STABILITY IN THE EARTH'S CRUST AND ALTERATION. IN CONNECTION WITH AN INVESTIGATION OF DOLOMITES OF THE UPPER HORIZONS OF KAZANIAN AGE NEAR THE CITY OF KAZAN']: Tr. O-va yestestvoispyt. pri Kazanskom Univ., t. 50, vyp. 6, 1925.

10. Lisichkin, S.M., Ozokerity i tsereziny. [OZOCERITES AND WAXES]: Azneftеizdat, 1936.

11. Muratov, V.N., Obrazovaniye ozokerita i formirovaniye yego zalezhey. [FORMATION OF OZOCERITE AND ITS DEPOSITS]: Gostoptekhizdat, 1954.

12. Noinskiy, M.E., Samarskaya luka. [SAMARSKAYA LUKA]: Tr. O-va yestestvoispyt. pri Kzanskom Uni., t. 45, vyp. 4-6, 1913.

13. Osipova, A.I., Usloviya obrazovaniya dolomitov v Ferganskom zalive peleogenovogo morya. [CONDITIONS OF FORMATION OF DOLOMITE IN THE FERGAN GULF OF THE PALEOGENE SEA]: Tr. geol. in-ta Akad. Nauk SSSR, vyp. 4, 1956.

14. Pustovalov, L.V., Petrografiya osadochnyk porod. [PETROGRAPHY OF SEDIMENTARY ROCKS]: Gostoptekhizdat, 1940.

15. Sindeyeva, N.D., Selen i tellur v mestorozhdeniyakh razlichnykh geneticheskikh tipov. [SELENIUM AND TELLURIUM IN DEPOSITS OF DIFFERENT GENETIC TYPES]: Izvestiya, Akad. Nauk SSSR, ser. geol., no. 5, 1958.

16. Strakhov, N.M., Diagenez osadkov i yego znacheniye dlya osadochnogo rudoobrazovaniya. [DIAGENESIS OF SEDIMENTS AND ITS SIGNIFICANCE FOR SEDIMENTARY ORE DEPOSITION]: Izvestiya, Akad. Nauk ser. geol., no. 5., 1953.

17. __________, O tipakh i genezise dolomitovykh porod (sostoyaniye znaniy). [TYPES AND ORIGIN OF DOLOMITIC ROCKS (STATE OF KNOWLEDGE)]: Tr. geol. in-ta Akad. Nauk SSSR, vyp. 4, 1956.

18. Tatarskiy, V.B., Litologiya neftenosnykh karbonatnykh porod Sredney Azii i proiskhozhdeniye neftenosnykh dolomitov. [LITHOLOGY OF PETROLIFEROUS CARBONATE ROCKS OF MIDDLE ASIA AND THE ORIGIN OF PETROLIFEROUS DOLOMITES]: GONTI, 1939.

19. __________, O formakh zaleganiya bitumov v karbonatnykh porodakh po dannym mikroskopii. [THE MODE OF OCCURRENCE OF BITUMENS IN CARBONATE ROCKS ACCORDING TO MICROSCOPIC DATA]: Zap. Vses. mineralog. o-va, t. 77, no. 3, 1948.

20. __________, K probleme genezisa nefti. [THE PROBLEM OF ORIGIN OF PETROLEUM]: Vestn. Leningr. un-ta, ser. biol., geogr. i geol., no. 7. 1954.

21. Teodorovich, G.I., Dolomit zamescheniya v verkhnem paleozoye Uralo-Volzhskoy oblasti. [REPLACEMENT DOLOMITE IN THE UPPER PALEOZOIC OF THE VOLGA-URALS REGION]: Byul. Mosk. o-va ispyt. prirody, otd. geol., t. 20, no. 3-4, 1945.

22. __________, O genezise dolomita osadochnykh obrazovaniy. [THE ORIGIN OF DOLOMITE IN SEDIMENTARY ROCKS]: Doklady, Akad. Nauk SSSR, t. 53, no. 9, 1946.

23. Khvorova, I.V., Dolomita karbona i morskoy nizhney permi zapadnogo sklona Yuzhnogo Urala. [CARBONIFEROUS AND MARINE LOWER PERMIAN DOLOMITES OF THE WESTERN SLOPE OF THE SOUTHERN URALS]: Tr. in-ta geol. nauk Akad. Nauk SSSR, vyp. 4, 1956.

24. Khodak, Yu.A., Formy zaleganiya bitumov v kembriyskikh otlozheniyakh Aldanskogo rayona Yakutskoy ASSR. [MODE OF OCCURRENCE OF BITUMENS IN THE CAMBRIAN DEPOSITS OF THE ALDAN REGION, YAKUT SSR]: Doklady, Akad. Nauk SSSR, t. 105, no. 3, 1955.

25. Kholodov, V.N., K voprosu o proiskhozhdenii suturo-stilolitovykh shvov. [ON THE ORIGIN OF SUTURED-STYLOLITIC SEAMS]: Izvestiya, Akad. Nauk SSSR, ser. geol., no. 2, 1955.

26. __________, and I.A. Kondrat'yeva, O nekotorykh osobennostyakh obrazovaniya dolomitovykh porod Turkestanskogo yarusa paleogena Fergany. V. sb. Voprosy Mineralogii i Osadochnykh Obrazovaniy. [CERTAIN CHARACTERISTICS OF FORMATION OF PALEOGENE DOLOMITIC ROCKS OF THE TURKESTAN STAGE IN FERGANA. IN THE BOOK: PROBLEMS OF MINERALOGY AND SEDIMENTATION]: Bk. 2, L'vov, 1955.

27. Kholodov, V. N., G. V. Komarova and I. A. Kondrat'yeva, O vliyanii konsedimentatsionnoy skladchatosti na protsess karbonatoobrazovaniya. Stat'ya I. [THE EFFECT OF FOLDING SYNCRONOUS WITH SEDIMENTATION ON THE DEPOSITION OF CARBONATE ROCKS. ARTICLE I]: Izvestiya, Akad. Nauk SSSR, ser. geol., no. 11, 1956.

28. Kholodov, V. N., G. V. Komarova and I. A. Kondrat'yeva, O vliyanii konsedimenattsionnoy skladchatosti na protsess karbonatoobrazovaniya. Stat'ya 2. [THE EFFECT OF FOLDING SYNCRONOUS WITH SEDIMENTATION ON THE DEPOSITION OF CARBONATE ROCKS. ARTICLE 2]: Izvestiya, Akad. Nauk SSSR, ser. geol., no. 4, 1957.

29. Erickson, R. L., A. T. Myers and C. A. Horr, Association of uranium and other metals with crude oil, asphalt and petroliferous rock: Bull. Amer. Assoc. Petrol. Geologists, vol. 38, no. 10, 1954.

30. Gott, G. B. and R. L. Erickson, Reconnaisance of uranium and copper deposits in part of New Mexico, Colorado, Utah, Idaho and Wyoming: U. S. Geol. Survey Circ., 1952.

31. Henbest, L. G., Unusual nuclei in oolites from the morrow group near Fayetteville, Arkansas: J. Sedim. Petrol., vol. 15, no. 1, 1945.

32. Krauskopf, K. B., Sedimentary deposits of rare metals: Fiftieth Anniversary Volume, Economic Geology, 1955.

33. Smith, P. V., Studies on origin of petroleum: Occurrence of hydrocarbons in recent sediments: Bull. Amer. Assoc. Petrol. Geologists, vol. 38, no. 3, 1954.

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AGE RELATIONS AMONG THE ROCKS OF THE KHIBINY ALKALIC MASSIF

by

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For several years the author has studied the mineralogy, petrography and age relations between rischorrites, the rocks of the fine-grained complex and foyaites. The solution of the problem of age relations among these complexes should provide a definite enough answer to the question of the sequence of formation of the Khibiny rocks, on which there is no agreement among the different investigators [1 - 4].

The factual material collected by the author on the contact relations between rischorrites and the fine-grained nepheline syenites, and of the fine-grained rocks and foyaites, and the results of laboratory studies (determination of the optical orientation of potassic feldspars, of accessory minerals and of the chemical and mineralogical composition) confirm the age sequence suggested by B. M. Kupletskiy, in which rischorrites and the fine-grained nepheline syenites are considered to be later than the khibinites and foyaites.

For a number of years the author studied rischorrites and the fine-grained aegirine-hornblende nepheline syenites and foyaites in the vicinity of the Gakman River valley (Mt. Yukspor) (Figure 1).

The rischorrites are coarse-grained light-gray or greenish-gray rocks with a characteristic poikilitic texture. They are composed mainly of potassic feldspar (Table 1), nepheline, aegirine and arfvedsonite. Lepidomelane, sphene, pectolite, eucolite and some other minerals occur as accessories.

The quantitative mineralogical composition (mode) of the rischorrites is given in Table 2 and their chemical composition in Table 3.

To discover the relationship between the rischorrites and the fine-grained aegirine-hornblende nepheline syenites and between nepheline syenites and foyaites, four traverses were made from south to north (across the strike from the rischorrite exposures through the fine-grained complex and its contact with foyaite).

A study of the contact between rischorrite and the fine-grained aegirine hornblende nepheline syenite shows it to be gradational. The contact between these rocks on Mt. Yukspor was first located by the author in 1953. The surface of the contact strikes almost east-west and dips 60-70° to the north.

There is no significant change in the rischorrite as it approaches the contact with porphyritic aegirine-hornblende nepheline syenite (a variety in the fine-grained rock complex). However, within about 15 cm from the contact it almost entirely loses its poikilitic texture and becomes somewhat more leucocratic. Directly at the contact with the porphyritic aegirine-hornblende nepheline syenite, the potassic feldspar of rischorrite is rendered somewhat turbid by numerous minute inclusions of aegirine.

Besides the large potassic feldspar and nepheline crystals, the contact rock contains very small grains of the same minerals measuring tenths of a millimeter. Locally, near contact with porphyritic aegirine hornblende nepheline syenite, rischorrite is slightly enriched in sphene and eucolite and its nepheline content rises while the content of potassic feldspar decreases.

The thickness of the fine-grained complex in the Mt. Yukspor region is of the order of 400 m. In the south they gradually pass into rischorrite and in the north are in sharp contact with foyaite.

In his description of the rocks of the fine-grained complex, M. S. Afanas'yev distinguishes the following varieties (from south to north): 1) porphyritic aegirine-hornblende nepheline syenite, 2) fine-grained aegirine-hornblende syenite, 3) fine-grained mica-hornblende nepheline and 4) aegirine-mica nepheline syenite.

The semi-instrumental geologic mapping by the author and observations in the field showed that this subdivision of the rocks of the fine-grained complex is not quite correct.

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[1]O vozrastnykh sootnosheniyakh porod khibinskogo shchelochnogo massiva.

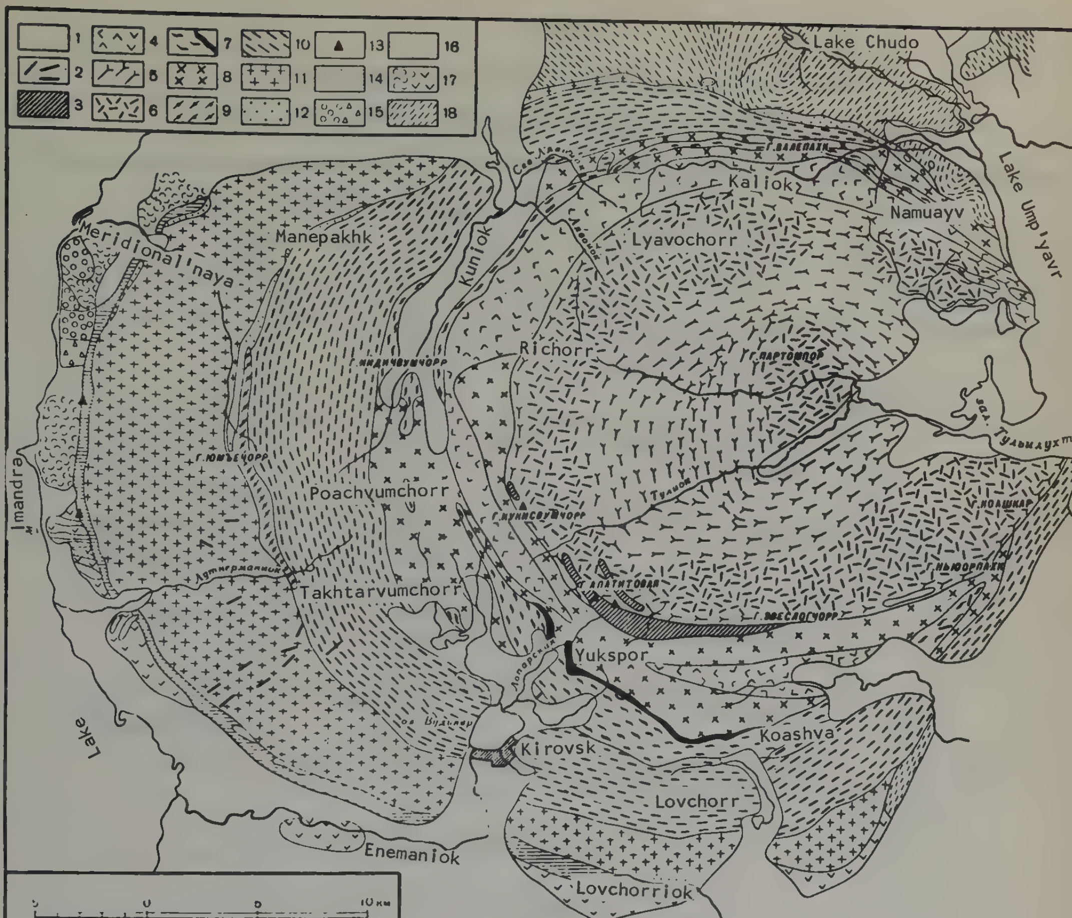

FIGURE 1. Geological map of Khibiny massif. Compiled by Ye.N. Volodin [1].

1 - Quaternary deposits. Alkalic rocks of the Khibiny pluton: 2 - young dikes, 3 - fine-grained mica-aegirine-hornblende nepheline syenites; 4 - medium-grained aegirine nepheline syenite; 5 - trachytoid foyaites; 6 - granitoid foyaite; 7 - ijolite-urtite, malignite, apatite rock; 8 - rischorrites; 9 - alkalic syenite porphyry; 10 - trachytoid khibinite; 11 - granitoid khibinite; 12 - alkalic and nepheline syenites of the first intrusive phase. Paleozoic (?): 13 - schists and hornfelses. Proterozoic: 14 - plagioclase-pyroxene, amphibole and other hornfelses; 15 - quartz diabase and granophyre; 16 - meta gabbro and meta diabase; 17 - pillow lava, amygdaloidal lava, green schists and tuff - sedimentary sequence. Archean: 18 - gneisses.

1. The rocks grouped by Afanas'yev under numbers 2, 3 and 4 are rarely found in situ but usually occur in talus and hence it is impossible to group them into a number of varieties.

2. When these rocks do occur in situ it is still impossible to subdivide them, for locally they are enriched in mica or aegirine, or in both minerals.

The writer proposes that the rocks of the fine-grained complex be grouped into two varieties: a) the medium-grained porphyritic aegirine hornblende nepheline syenite and b) the medium-grained aegirine nepheline syenite.

a) The medium-grained porphyritic aegirine-hornblende nepheline syenite has massive or gneissoid structure and contains rather large potash feldspar and nepheline phenocrysts up to 3 x 1 cm and 2 x 2 cm, respectively, which stand out sharply against the dark-gray fine-grained groundmass composed of nepheline, potassic feldspar (Table 1), aegirine, arfvedsonite, lepidomelane, sphene, eucolite and other minerals.

The potassic feldspar (Table 1) in this variety of the fine-grained rocks has optical orientation intermediate between orthoclase and microcline, and in this respect does not differ from the feldspar of rischorrite.

Table 1

U-stage data on Potash Feldspar from Rischorrite, Rocks of the Fine-Grained Complex and Foyaite

Rock	Place of sampling	Optic orientation of potash feldspar	2V	Type of potash feldspar
Rischorrite	2—3 m from contact with porphyritic aegirine-hornblende nepheline syenite	γ 87° P/001 β 7° α 82°	—74°	Orthoclase
"	Near contact with porphyritic aegirine-hornblende nepheline syenite	γ 89° P/001 β 12° α 84°	—64°	Intermediate between orthoclase and microcline. Nearer to orthoclase
Porphyritic aegirine-hornblende nepheline syenite	Near contact with rischorrite	γ 77° P/001 β 12° α 88°	—58°	Intermediate between orthoclase and microcline
"	1—2 m from contact with rischorrite	γ 89° P/001 β 12° α 89°	—72°	Orthoclase
"	3—5 m from contact with rischorrite	γ 86° P/001 β 20° α 70°	—72°	Intermediate between orthoclase and microcline
Foyaite	At contact with the rocks of the fine-grained complex	γ 83° P/001 β 18° α 73°	—82°	Microcline

Table 2

Modes of Rischorrites, Rocks of the Fine-Grained Complex Foyaite

Minerals	Rischorrite composition in %	Fine-grained complex composition in % (porphyritic aegirine-hornblende nepheline syenite)	Foyaite composition in %
Potash feldspar	52,7	48,07	69
Nepheline	39,1	38,47	21
Dark minerals	8,2	13,46 (aegirine & arfvedsonite 12,56 and sphene 0,9)	10
Authors	A. V. Galakhov L. S. Borodin	Yu. S. Slepnev	L. S. Borodin

Note: Comma represents decimal point.

The mode of the porphyritic aegirine-hornblende nepheline syenite based on analysis of 16 most typical specimens is given in Table 2. It shows that in their content of essential minerals (potassic feldspar, nepheline and of the varietal and accessory minerals (arfvedsonite, aegirine, sphene, lepidomelane, eucolite and others) they are rather near rischorrite (Table 2).

Chemically (Table 4) the porphyritic aegirine-hornblende nepheline syenite is also rather near rischorrite (Table 3).

The porphyritic aegirine-hornblende nepheline syenite, mainly with gneissoid structure, rather frequently contains thin (1 - 2 cm to 10 - 20 cm) irregular veinlets composed of hair-like

Table 3

Chemical Composition of Rischorrite (average sample)

Oxides	Composition, %	Recalculation into A.N. Zavaritskiy's parameters	
SiO_2	51,59	859	872 . . . . S
TiO_2	1,01	13	
Al_2O_3	22,59	221 × 2=442 . . . . A	
Fe_2O_3	2,51	16 × 2=32—4=28	52 | 98 . . . B
FeO	1,76	22	
MnO	0,18	2	
MgO	0,75	18	
CaO	1,55	28	
BaO	—	—	
Na_2O	7,22	117	223—221—2×2=4 C
K_2O	9,96	106	
P_2O_5	0,25		
F	0,14	A=442	a=31,2
Co_2	0,11	S=872	s=61,6
H_2O^+	0,32	B=98	b= 6,9
H_2O^-	0,29	C=4	c= 0,3
Total	100,23	N=1416	100
Auxiliary characteristics f' = 53; m' = 18; c' = 23; n = 52; t = 1; φ = 28 Literary source A. V. Galakhova			

Potash feldspar—52.7%, nepheline—39.1%, dark minerals—8.2%

Note: Comma represents decimal point.

accumulations of late aegirine and lamprophyllite. This textural variety also contains abundant pegmatite veins whose attitude is governed by the gneissoid structure of the rock. The pegmatite veins follow the undulations of the enclosing rock. Numerous observations on the gneissoid structure (lineation, tabular habit of the crystals) make it clear that it is due to directed pressure acting in a complex tectonic setting (dynamo-metamorphism). The porphyritic aegirine-hornblende nepheline syenite passes gradually into fine-grained aegirine-hornblende nepheline syenite directly in contact with foyaite.

b) The fine-grained aegirine-hornblende nepheline syenite is a dark-gray massive rock. It is composed of potassic feldspar with optical orientation intermediate between orthoclase and microcline, nepheline, arfvedsonite and lepidomelane. Sphene, apatite, eucolite and other minerals occur in smaller amounts. The grains of the essential minerals are no more than 1 - 3 mm in length. The chemical analyses of the fine-grained aegirine-hornblende nepheline syenite are given in Table 5. Its mode is near to that of the porphyritic variety.

At the contact with foyaite the fine-grained aegirine-hornblende nepheline syenite is more dense and sometimes contains fragments (xenoliths) of foyaite, evidently entrapped during the intrusion of the fine-grained complex.

To study the contact between the fine-grained rocks and foyaites a series of thin sections cut from samples collected 3 - 5 cm apart was examined. The fine-grained aegirine-hornblende nepheline syenite at about 0.6 - 0.4 cm from the contact with foyaite is characterized by very fine grain with the individual minerals measuring tenths of a millimeter. It is composed mainly of potassic feldspar and nepheline. Arfvedsonite and eucolite are present in smaller amounts. Albite, enigmatite and sphene occur directly at the contact with foyaite.

The foyaite of the northernmost part of the

Table 4

Chemical Analysis of Porphyritic Aegirine-Hornblende Nepheline Syenite with Gneissoid Structure

Oxides	Composition, %	Molecular amounts and recalculation into A.N. Zavaritskiy's parameters	
SiO_2	53,68	893	904 . . . . S
TiO_2	0,90	11	
Al_2O_3	21,00	$206\times2=412$	. . . . A
Fe_2O_3	2,35	$14\times2=28-24=4$	
FeO	2,40	33	40 } 93 . . . . . . B
MnO	0,27	3	
MgO	1,34	33	
CaO	1,14	20	
Na_2O	8,68	140	$218-206=12\times2=24$ . . . C
K_2O	7,52	78	
H_2O^+	0,14	7	$A=412$ $a=28,7$
H_2O^-	0,56	31	$S=904$ $s=63,1$
P_2O_5	0,23	1	$B=93$ $b=6,5$
			$C=24$ $c=1,7$
Total	100,21		$N=1433$ 100

L. B. Tumilovich, Analyst, 1954
Auxiliary characteristics
$f' = 44$; $m' = 36$; $c' = 21$; $n = 32$; $t = 1$; $\varphi = 4$.

Potash feldspar 48.07%, nepheline 38.47%, dark minerals 13.46%

Note: Comma represents decimal point.

section is a coarse-grained light-gray rock composed of microcline (in rischorrite and the rocks of the fine-grained complex the potassic feldspar, as has already been mentioned, has optical orientation intermediate between orthoclase and microcline), nepheline, aegirine and arfvedsonite. Sphene, ilmenite, lamprophyllite, apatite and other minerals are present in small amounts.

The mode of the foyaite is given in Table 2. Clearly the content of both the essential (potassic feldspar and nelheline) and accessory minerals (lamprophyllite, ilmenite, apatite) in foyaite is sharply from that in rischorrite and the rocks of the fine-grained complex.

The chemical analysis of an averaged sample of foyaite confirms the difference between the composition of foyaite and of rischorrite and the fine-grained rocks.

SUMMARY

1. The rischorrite and the fine-grained aegirine-hornblende nepheline syenite of the Khibiny alkalic massif were formed as a single geological body by a one-phase intrusion of a definite fraction of magma.

2. The genetic relationship between the fine-grained aegirine hornblende nepheline syenite and rischorrite is established on the basis of the following facts:

a) the change from the fine-grained aegirine-hornblende nepheline syenite to rischorrite is gradational;

b) both rocks contain potassic feldspar with the same optical orientation;

c) the same accessory minerals (sphene, pectolite, lepidomelane, eucolite and others) are present in both rocks; and

d) both rocks have similar chemical and mineralogical composition (as shown by the

Table 5

Chemical Analyses of Fine-Grained Aegirine-Hornblende Nepheline Syenites

Oxides	Aegirine-hornblende nepheline syenite		Aegirine nepheline syenite	
	Composition, %	Recalculation to A.N. Zavaritskiy's parameters	Composition, %	Recalculation to A.N. Zavaritskiy's parameters
SiO_2	54,88	914 } 927 . . . . S	49,86	830 } 858 . . . . S
TiO_2	1,06	13	2,24	28
Al_2O_3	17,60	174×2=348 . . . . A	14,40	141×2=282 . . . . . . A
Fe_2O_3	6,47	41×2=82—70=12 } 45 } 77 *B*	10,43	65×2=130—94=36 } 183 *B*
FeO	2,18	30	2,11	29
MnO	0,24	3	1,35	4
MgO	0,57	14	1,28	32
CaO	1,02	18	4,64	82
Na_2O	8,60	139 } 209—174=35×2=70 *C*	7,47	120 } 188—141=47×2=94 *C*
K_2O	6,62	70	6,47	68
H_2O^-	0,12		0,18	9
H_2O^+	0,96		0,34	18
P_2O_5	0,19		0,17	1
Total	100,51		100,94	

L. B. Tumilovich, analyst, 1954

A=348	*a*=24,6	*A*=282	*a*=19,9
C= 70	*c*= 4,9	*C*= 94	*c*=12,9
B= 77	*b*= 5,4	*B*=183	*b*= 6,6
S=927	*s*=65,1	*S*=858	*s*=60,6
N=1422	100	*N*=1417	100

Auxiliary characteristics

f' = 58; m' = 18' c' = 23; n = 59; t = 1; φ = 16.

f' = 38; m' = 12; c' = 45; n = 52; t = 3; φ = 20.

Table 6

Chemical Composition of Foyaite (average sample)

Oxides	Composition %	Recalculation to A.N. Zavaritskiy's parameters	
SiO_2	55,75	928	934 . . . . S
TiO_2	0,46	6	
Al_2O_3	23,40	229—191=38−21=17×2=34	102 B
Fe_2O_3	3,44	22×2=44	
FeO	—	—	
MnO	0,15	2	
MgO	0,90	22	
CaO	1,19	21	C
Na_2O	7,57	122	191×2=382 . . . . A
K_2O	6,58	69	
H_2O^+ H_2O^-	0,62	A=382 a=26,5	
Total	100,06	C=21 c= 1,5 B=102 b= 7,1 S=934 S=64,9 N=1439 100	
T. A. Kapitonova, analyst, 1954 Literary source L. S. Borodin			

Auxiliary characteristics

a' = 33; f' = 43; m = 22; n = 64; t = 0.7; φ = 43
Potash feldspar -69%; nepheline - 21%,
dark minerals - 10%

data of micrometric and chemical analyses of average samples).

REFERENCES

1. Yeliseyev, N. A., I. F. Ozhinskiy and Ye. N. Volodin, Geologicheskaya karta Khibinskikh tundr. [GEOLOGIC MAP OF THE KHIBINA TUNDRAS]: Tr. Leningr. geol. upr., vyp. 19, 1935.

2. Kupletsliy, B. M., Petrografiya tsentral'noy chasti Khibinskikh tundr. V sb. Khibinskiye apatity. [PETROGRAPHY OF THE CENTRAL PART OF THE KHIBINA TUNDRAS. IN THE BOOK: KHIBINA APATITES]: Vyp. 1, Leningrad, 1930.

3. Kupletsliy, B. M., Geologo-petrograficheskiy ocherk Khibinskikh tundr. V kn. Akad. V.I. Vernadskomu k 50-letiyu nauchnoy i pedagogicheskoy deyatel'nosti, t. 2. [GEOLOGICAL AND PETROGRAPHIC DESCRIPTION OF THE KHIBINA TUNDRAS. IN THE BOOK: V. I. VERNADSKIY'S VOLUME HONORING 50TH ANNIVERSARY OF HIS SCIENTIFIC AND PEDAGOGICAL ACTIVITY]: Izd. Akad. Nauk SSSR, 1936.

4. Mineraly Khibinskikh i Lovozerskikh tundr. [MINERALS OF THE KHIBINA AND LOVOZERO TUNDRAS]: Izd. Akad. Nauk SSSR, 1937.

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SPICULE ANALYSIS AND ITS USE IN GEOLOGY[1,2]

by

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At present various micropaleontological methods are rather widely used in geology for the study of sedimentary rocks. The methods of foraminiferal, diatom and pollen analysis are well known and successfully used, especially in the investigation of Tertiary and Quaternary deposits. Familiarity with samples of marine deposits of different ages containing abundant spicules or spines of sponges and careful study of these fossils[3] have convinced the writer that sponge spicules, and hence the sponges themselves, inasmuch as their classification is based on the structure of the spicules, can be used in the study of sedimentary rocks as successfully as foraminifera or diatoms.

This idea cannot be considered new and original, for it comes to mind as soon as one reviews the first special works devoted to the classification and description of fossil sponge spicules found in great abundance in some sedimentary rocks [3, 6]. There are even several papers (W. F. Bailey [1] and others) describing the use of spicules in stratigraphic deductions. However, the idea of using sponge spicules in the study of sedimentary rocks and in historical geology in general has not been widely accepted.

The main prerequisites to the use of animal or plant remains in geological investigations is that they be well preserved as fossils and sufficiently abundant. Sponges, or rather parts of their skeletons, satisfy these requirements. Fossil siliceous sponge spicules are so well preserved, as a rule, that it is often impossible to distinguish by their state of preservation alone the spicules from Cenozoic or even Mesozoic rocks from the spicules of the sponges living in the modern seas. Sponge remains in the form of their skeletal elements, i. e., siliceous spicules, are very often found in greater or less abundance in sedimentary rocks. They are known from the Carboniferous limestones of Great Britain and Ireland [3, 8, 11 and others]. The siliceous sponge spicules from the Tertiary rocks of New Zealand [6] and from the Silurian rocks of the southwestern part of Australia [5] have been described in considerable detail. Beds filled with sponge spicules have been found in the Mesozoic (Cretaceous, Jurassic) and Paleozoic (Devonian) deposits of Western and Central Europe [2, 14]. In North America, spicules have been described from rocks of different ages from the Silurian to the Quaternary [4, 9, 10, 12, 13]. Sponge spicules are very often found in cores taken by geologists with special devices from the sea and ocean floors.

The existing data on fossil sponge spicules are still rather scant, but it is possible, even now, to formulate certain preliminary principles of spicule analysis.[4]

1. The taxonomy of the sponges is based on the structure of the skeleton and the character of its constituent parts, or spicules. Inasmuch as the form of the spicules is an important systematic criterion, a study of isolated spicules enables one to determine the order, family and genus of the sponges which inhabited the locality where the spicules were deposited. Sometimes the form of the spicules is so characteristic that the species of a sponge can be determined from isolated spicules.

2. The majority of sponges have siliceous skeletons composed of spicules connected by

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[1]Spikul'nyy analiz i yego primeneniye v geologii.

[2]Evidently the method of spicule analysis proposed in this paper is applicable mainly to Quaternary forms. Nevertheless the paper deserves publication in Izvestiya, Akad. Nauk SSR, ser. geol., because it brings to the attention of geologists a group of fossils which has not been used in stratigraphic work. Editors.

[3]In addition to the analyses of factual material given at the end of this paper, the author has made analyses of samples from the Upper Cretaceous rocks of the Transuralia and Paleogene deposits of Southern Urals, containing abundant sponge spicules.

[4]By spicule analysis in this case is meant the method used in the study of fossil sponge spicules and the application of the obtained data to geological problems.

organic tissue called spongin. Only a few sponges have skeletons in the form of a solid framework in which the individual spicules are fused together (it is these sponges that are most often found as complete fossils).

The spicules are divided into macroscleres and microscleres. The macroscleres are usually over 0.1 mm long, or from 0.1 to 1 mm on the average, and from 0.003 to 0.03 mm thick; the microscleres average from 0.01 to 0.1 mm in length and about 0.001 - 0.002 mm in thickness. The macroscleres (monacts, diacts, triacts, tetracts, etc.) differ from the microscleres (chelas, sigmas, asters) not only in size but also in their function in the sponge skeleton; the macroscleres constitute the principal part of the skeleton and the microscleres play a secondary role.

When a sponge dies its skeleton falls apart and the spicules are deposited on the bottom of the basin where the sponges lived. In the sedimentary rocks of different ages, at least beginning with the Mesozoic, sponge spicules are common and sometimes very abundant. The siliceous spicules are durable and usually well preserved as fossils, and may, therefore, serve for the determination of the sponges and hence for spicule analysis.

3. Sponges are widespread in the modern oceans and there are reasons to believe that in the past geological epochs they were even more abundant and varied than now. Most sponges are typically marine but there are also fresh and brackish water sponges. Among the marine sponges there are sthenohaline and euryhaline, sthenothermic and eurythermic; warmth- and cold-loving forms which may serve as indicators of temperature and salinity of the basins in which they lived. Sponges live on the floor of the sea from the littoral to the abyssal depths, but are most abundant on the shelf and the continental slope (down to a depth of 600-800 m) and many of them are restricted in their vertical distribution to definite depths. Thus, sponges are good indicators of the physicochemical conditions of their habitat.

The study of spicules in sedimentary rocks provides a means of determining whether the rocks are marine or continental and of estimating with considerable accuracy the depth of the basin and the various physicochemical conditions in it (temperature, salinity). The data of spicule analysis may be used in paleogeographic and stratigraphic analysis of sedimentary rocks.

Spicule analysis, in the author's opinion, is no less important then the analogous diatom and pollen analyses and possibly has a number of advantages over them due to the characteristics of the sponges. For example, since sponges are benthonic organisms, the transport of their remains (spicules) from the place where they lived is restricted. Moreover, because of their massiveness and durability, spicules are better preserved as fossils than, for example, the delicate diatom tests. The method of preparation of spicules for study is very simple. In many cases it is enough to treat a small sample with hydrochloric acid or an alkali and after careful washing to imbed it in canada balsam or some other medium of high refractive index.

Further improvements of the methods of spicule analysis will come as knowledge of the systematics, ecology and distribution of modern and fossil sponges increases. The greatest need at present for the development of spicule analysis is to collect factual data on fossil sponge deposits.

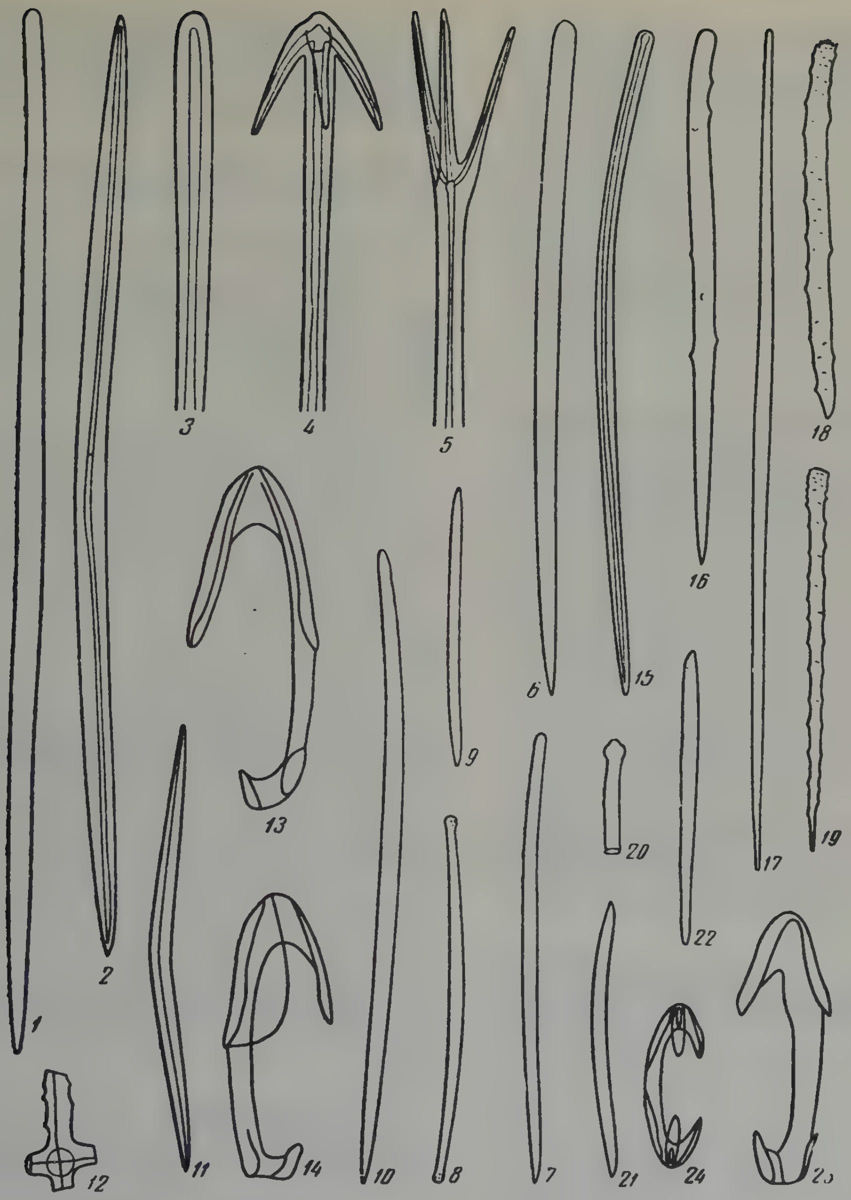
Let us apply spicule analysis to a few samples of sedimentary rocks at our disposal.

Spicule deposits found in Antarctica on the shore of Lake Dlinnoye (Princess Elizabeth Land, Vestfold Hills)[5] have a felt-like appearance and are composed of very long thread-like spicules by means of which the sponges of the order Tetraxonida attach themselves to a muddy bottom. The sample contains other spicules which provide information on the sponge fauna and on the depth of water in which it lived.

The more characteristic of these sponges are shown in Figures 1-14: style (Figure 1) — 0.76 mm long, 0.01 mm thick (order Mycale); oxea (Figure 2) length, 0.66 mm, thickness 0.022 mm (order Tetraxonida); style (Figure 3) thickness 0.05 mm (Tetraxonida) anatriaene (Figure 4), length of branches 0.08 mm (Craniella); protriaene (Figure 5), length of branches 0.13 mm (Craniella); style (Figure 6) 0.5 mm long, 0.012 mm thick (fam. Myxillidae); style (Figure 7) 0.31 mm long, 0.01 mm thick (fam. Myxillidae); tylote with tubercules at the ends (Figure 8), length 0.26 mm, thickness 0.008 mm (genus Iophon); oxea (Figure 9) length 0.2 mm, thickness 0.008 mm (Tetraxonida or Cornacuspongia); style (Figure 10) 0.45 mm long, 0.016 mm thick (fam. Myxilidae); oxea (Figure 11) 0.33 mm long, 0.014 mm thick (Tetraxonida); hexact (Figure 12) thickness of rays 0.016 mm (triacts; anisochelas (Figures 13 and 14), 0.09-0.104 mm (order Mycale).

The occurrence of numerous spicules of the anatriaene and protriaene type together with oxeas (Figures 2, 4, 5, 11) in the deposit indicates that sponges of the genus Craniella were abundant here, namely Craniella leptoderma (Sollas). In the antarctic waters this species is found at a depth of 122-342 m. Another sponge whose spicules are found in the samples (Figures 7, 8, 10) is of the genus Iophon, most

[5]The samples (two, Nos. 330 and 343) were collected by Ye.S. Korotkevich, geographer of the Complex Antarctic Expedition, Acad. Sci., USSR, 1955-1956, and given to the writer for analysis.



Sponge spicules from sediments on the shore of Lake Dlinnoye (Princess Elizabeth Land, Vestfold Hills).

1 - style, x 170; 2 - oxea, x 170; 3 - style (fragment), x 170; 4 - anatriaene, x 170; 5 - protriaene, x 170; 6, 7 - styles, x 170; 8 - tylote with tubercules at the ends, x 170; 9 - oxea, x 170; 10 - thornote style, x 170; 11 - oxea, x 170; 12 - hexact, x 170; 13, 14 - chelas with unlike ends, x 430.

Sponge spicules from a core of bottom sediments taken in the region of Franz Joseph Land (Central part of the Arctic basin).

15 - subtilostyel, x 170; 16 - acanthose style, x 170; 17 - style x 170; 18, 19 - acanthostyles, x 170; 20 - tylostyle (fragment), x 170; 21 - oxea, curved, blunt, x 170; 22 - thornote, x 170; 23 - chela with unlike ends, x 430; 24 - three-pronged anchor, x 430.

likely Iophon radiatus Topsent, which lives at a depth of 26-350 m. There are occasional macro- and microscleres (Figures 1, 13, 14) of a sponge of the order Mycale (depth of habitat 37-300 m) and the hexacts of glass sponges (order Triaxonida) which live in the Antarctica at a depth of over 100 m. Thus, when this area of the Antarctic coast was covered by water of normal salinity the depth at which the spicules were deposited was approximately 100-200 m. The isolation of this area from the open ocean resulted in extinction of the sponges (caused by abnormally high salinity, poor aeration, etc.) and their remains are now found on the shore of Lake Dlinnoye.

Analysis of a core from the central part of the Polar basin. During the work of the High Latitude Complex Arctic Expedition on the ice breaker F. Litke in 1955, geologist N. A. Belov sampled the bottom sediments in the region to the north of Spitzbergen and Franz Joseph Land with Kudinov's piston corer. One of the cores from station 5 (83° 09' N lat., 53° 31' E. long) was analyzed for its spicule content. The core is 352 cm long and was taken at the depth of 3044 m. The geologists who studied the core subdivided it as follows: section 1 (from the top) 7 cm thick; section 2, 12 cm; section 3, 5 cm; section 4, 1.5 cm; section 5, 2.5 cm; section 6, 1.5 cm, and so forth.

Section 1 contains small spicule fragments of the abyssal sponge Thenea muricata abyssorum Koltun and also calcareous spines of the holothurian Elpidia glacialis Theel, usually living in this region in great numbers at a depth of 2000-4000 m.

Section 2. Oxeas (Figure 21) characteristic of genus Haliclona are always present. These spicules are 0.2 - 0.24 mm long and 0.006 - 0.011 mm thick. It is possible that they belong to Heliclona ventilabrum (Fristedt) living in the Arctic at a depth of 457-768 m. A few acanthose styles (Figures 18, 19) 0.28 - 0.3 mm long and 0.008 - 0.012 mm thick characteristic of the family Myxillidae were found and also thornote (Figure 22) about 0.220 mm long and 0.008 mm wide, as well as a three pronged anchor (Figure 24) about 0.050 mm long, spicules characteristic of Myxilla penduculata Lundbeck living in the Arctic at a depth of 28 to 1073 m.

Section 3 contains slightly acanthose styles (Figure 16), 0.400 - 0.450 mm in length and 0.014 - 0.16 mm in thickness. These spicules belong to Myxilla penduculata Lundbeck.

Section 4 contains occasional oxeas identical with the ones in the second section (Figure 21), and frequent spit-like styles (Figure 17) 0.510 - 0.650 mm long and 0.010 mm thick. Such styles are characteristic of the family Mycalidae. The anisochelas (Figure 23) 0.084 mm long present indicate that Mycale placoides (Carter) was common in this horizon. It lives in the Arctic at a depth of 31 - 1267 m. A single subtilostyle (Figure 15) 0.500 mm in length and 0.012 mm in thickness was found.

Section 5 contained sparse oxeas (Figure 21) and a fragment of tylostyle (Figure 20).

Section 6 contained a few oxeas (Figure 21).

In the rest of the sections representing the greater part of the core (322.5 cm) spicules do not occur at all or are found in fragments. At the very base of the core a single oxea (Figure 21) was found.

The spicule analysis of the core taken in the area north of Franz Joseph Land indicates that the depth of the sea at the time of deposition of layers 2, 3, 4, 5, and 6 was quite different from what it is now. Section 1 contains spines of the holothurian Elipidia glacialis Thee and spicules of the sponge Thenea muricata abyssorum Koltun (both forms characteristic of great depths in the Arctic), so this layer must have been desposited at the depth which exists in the sampling locality now, i.e., at the depth of the order of 3044 m. Section 2, however, does not contain deep water sponges, but contains instead spicules of Myxilla pedunculata Lundbeck and Haliclina ventilabrum (Fristedt) living in the Arctic at the depths corresponding to those of the shelf and the continental slope. Inasmuch as the vertical distributions of the first sponge ranges from 28 to 1073 m and of the second, from 457 to 768 m, it may be said that at the time of deposition of this layer the depth of the sea was between 400 and 800 m. If the rate of deposition of the first layer is taken as 30-40 mm per 1000 years [6] it follows that 2000 years ago the ocean floor at the sampling point subsided to the depth of from 800 to 3000 m.

The third section contained spicules of Myxilla penduculata Lundbec; section 4, spicules of Mycale placoides (Carter) living at the depth of 31 - 1267 m; and sections 5 and 6 contained occasional spicules of Haliclona ventilabrum (Fristedt). Therefore, sections 2, 3, 4, 5 and 6 may be grouped together on the basis of their faunas. Perhaps the depth of the sea during the deposition of these layers varied but not as much as in the first case.

Beginning with section 7, deposited about 10 - 11 thousand years ago, spicules are almost completely absent from the sediments. Whether this is due to a considerable increase in depth or to the ecological conditions which prevented

[6] The data on the rate of sedimentation and the time of deposition of marine sediments are taken from the work of V. N. Saks, N. A. Belov and N. N. Lapina, "Modern concepts of the geology of the Central Arctic," Priroda, No. 7, 1955.

the development of sponge faunas is difficult to say on the basis of the spicule analysis alone. However, there is no doubt that a very important physicochemical change was occurring at this locality at that time.

These examples of spicule analysis of sedimentary rocks confirm the possibility of using sponge spicules for reconstructing the conditions of deposition of the sediments. There is no doubt that even now spicule analysis can be used for paleogeographic reconstructions, at least within the Cenozoic era. The use of fossil sponge spicules for the determination of the ages of sedimentary rocks, and for stratigraphic purposes in general, is a more complex problem requiring special investigations. It will be necessary, especially at first, to study not a few isolated samples but numerous samples but numerous samples closely correlated with the data obtained by the already developed methods successfully used in geology for these purposes.

REFERENCES

1. Bailey, W.F., Micropaleontology and stratigraphy of the Lower Pennsylvanian of Central Missouri: J. Paleont., Sharon., Mass., vol. 9, no. 6, 1935.

2. Bartenstein, H., Schwamm-Nadeln im Mittel-Devon der Eifel und Ober-Devondes Ost-Thüringischen Schiefergebirges: Senckenbergiana Frankfurt, vol. 17, no. 5, 5-6, 1935.

3. Carter, H.J., On Fossil Sponge-spicules from the Carboniferous Strata on Ben Bulben, near Sligo: Ann. and Mag. Natur. History, vol. 5, no. 4, 1880.

4. Caster, K.E., Siliceous sponges from Mississippian and Devonian Strata of the Penn-York Embayement: J. Paleont., Menasha, Wis., vol. 13, no. 1, 1939

5. Dun, W., Note on the occurrence of Sponge-Remains in the Lower Silurian of New South Wales: P. Linnean Soc., N.S. Wales, vol. 22, 1897.

6. Hinde, G.J. and W.M. Holmes, On the Sponge-Remains in the Lower Tertiary Strata near Oamaru, Otago, New Zealand: J. Linnean Soc. (Zoology), vol. 24, no. 151, 1892.

7. Laubenfels, M.W., Porifera. Treatise on Invertebrate Paleontology. Part E, 1955.

8. Morton, G.H., On the Discovery of sponge Spicules in the Chert beds of Flintshire: P. Liverpool Biol. Soc., vol. 1, no. 69, 1887.

9. Needham, C.E., Sponge spicules from the Lower Ordovician of Wisconsin: Science, vol. 77, no. 2002, 1933.

10. Scott, H.W., Siliceous sponge spicules from the Lower Pennsylvanian of Montana: Amer. Midland Naturalist, v. 293, 1943.

11. Sollas, W.J., On the occurrence of sponge spicules in the Carboniferous Limestone of Derbyshore: Quart. J. Geol. Soc., vol. 55, 1899.

12. Weller, J.M., Siliceous sponge spicules of Pennsylvanian age from Illinois and Indiana: J. Paleont., no. 4, 1930.

13. Weller, J.M., Siliceous sponge spicules of Pennsylvanian age from Illinois and Indiana: Trans. Illinois Acad. Sci., vol. 23, 1931.

14. Zahálka, B., Die spongilitische Gesteine der böhmischen Kreide (Czech.): Publ. Fac. Sci. Univ. Masaryk., Brno, Teil 1, 2, 1935.

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BRIEF COMMUNICATIONS

JADEITE ROCK IN THE ULTRABASIC ROCKS OF THE POLAR URALS[1]

by

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In studying the gabbro-peridotite rocks of the Polar Urals (Kharamatalovsko-Voykarskiy region) it was found that pyroxenites are widely developed in the marginal parts of a dunite-peridotite intrusive and in fissures and dislocation zones of its central part. Among the pyroxenites, diopside-bearing varieties predominate, while diopside-enstatite, diopside-hypersthene pyroxenites and jadeite rocks are less abundant. The jadeite rocks were discovered by the author in 1951 in the highest part of the Ural Range, and because of their inaccessibility were not thoroughly investigated. However, even cursory observation showed that there is much similarity in the geological occurrence of jadeite and diopside rocks, and since the latter were studied in greater detail they will be briefly described.

Diopside rocks occur as straight sharply outlined bands, veins, thin branching veinlets, lenses and irregular bodies in strongly foliated and fractured dunites, peridotites and serpentinites. The pyroxenite veins often terminate in pyroxene aggregates or chains of pyroxene grains. The same structure is observed near and along thin feldspar veinlets. The thickness of the pyroxenite veins ranges from 1 cm to tens of meters.

The boundaries of the rectinlinear pyroxenite bodies are usually sharp without any change in texture or grain size at the margins. Often the pyroxene grains on the margins are larger than in the central parts of the bands. The irregular pyroxenite bodies have diffuse wavy outlines and are associated with large pyroxene porphyroblasts and aggregates lying within the enclosing dunite or serpentinite, either randomly or accordantly with the form of the pyroxenite bodies. The pyroxenites contain numerous inclusions of dunite and serpentinite in the form of angular fragments, blocks, sharply outlined bands and lenses ranging from 1 cm to 2-3 m in size. Large fresh crystals of diopside form branching veinlets in the dunite inclusions, occur in them as irregularly distributed grains or form sinuous rims around the xenoliths.

The diopside rocks are associated with plagioclase rocks composed mainly of calcic plagioclase (An_{45-90}) and more rarely with albitites and plagiogranites. The plagioclase rock forms numerous injections in dunites and serpentinites, sometimes extremely thin, sometimes up to 3 m in thickness. The injections contain inclusions of dunite enriched to a greater or less degree in plagioclase and diopside. The olivine of the inclusions is de-serpentinized, zoisitized, amphibolitized or bordered with reaction rims of diopside, enstatite or hypersthene.

The diopside rocks are dark-gray to light-green and range in texture from hornfelsic to granular and porphyroblastic. The diameters of the diopside grains are from 0.01 mm to 6 cm. Chemically, diopside is characterized by the presence of the jadeite molecule (up to 10%).

The jadeite rock was found in the uppermost part of the western slope of the range at the head of Levyy Kech'-Pel' creek in the narrow valley of its left tributary (northwestern slope of the Pay-Yer Range). Here among the schistose and serpentinized dunites there are two two northeast trending bodies of jadeite rock, their light color contrasting sharply with the black-green dunites. The jadeite rock produces talus of large blocks traceable for 80 m along the strike from the foot to the summit of the right bank of the creek valley. Each of the two bands is about 5 m. Both bands or veins of jadeite rock form straight sharp boundaries with serpentinized dunite. At the contact with the jadeite rock, the dunites are amphibolitized, being replaced by bluish-violet arfvedsonitic

[1]Zhadeitity v giperbazitakh polyarnogo Urala.

hornblende. Locally along the contacts, the dunites are carbonatized and chloritized.

Approximately 0.2 km down the creek, serpentinized dunites contain bands and veins of plagiogranite, albitite, muscovite-plagiogneiss, quartz-muscovite-albite and albite-tremolite rocks and also bands and areas of actinolite. The bluish-violet amphibole characteristic of jadeite rock contacts occurs also at the contact with plagiogranite and albitite injections in dunite. Towards the head of the valley and at the watershed dunites contain bands and veins of common diopside rocks.

The jadeite rock is light bluish-green, fresh, dense and fine-grained, the grains ranging from 0.01 to 3 mm. It is homogeneous, tough and has parallelopipedal jointing.

In thin sections the jadeite rock exhibits crystalloblastic, less commonly prismatic-granular or sheaf-like texture. The jadeite grains are usually anhedral, have serrated outlines and are tightly intergrown. The jadeite has wavy spotty extinction and is cut by numerous cracks, which, like the contacts between grains, contain dusty and lamellar aggregates of an ore mineral. Locally jadeite is zoned as shown by the variation in extinction and appearance of faint brownish and bluish-violet color.

Sometimes sharply twinned grains of albite containing inclusions of jadeite are observed between the grains of jadeite. The inclusions and the edges of jadeite grains in contact with albite are rimmed with secondary fibrous jadeite. Within the jadeite grains there are small vermiform and irregular grains of fresh albite forming narrow sinuous veinlets. The jadeite near these veinlets is also surrounded by secondary acicular faintly colored pyroxene. Small flakes of mica and grayish-brown aggregate of what appears to be zoisite occur in the cleavage cracks of jadeite and at contacts between jadeite grains.

The optical properties of jadeite are given in Table 2.

Powder photographs of jadeite (made at the Laboratory of the Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Academy of Sciences, USSR) gave interplanar distances very near those of standard jadeite as recorded by V.I. Mikheyev [2].

The presence in the investigated jadeite of some additional parameters absent from the standard sample is due, most likely, to an isomorphous admixture, probably of diopside, and also to the presence of small amounts of inclusions which could not be separated from the sample.

The chemical composition and optical

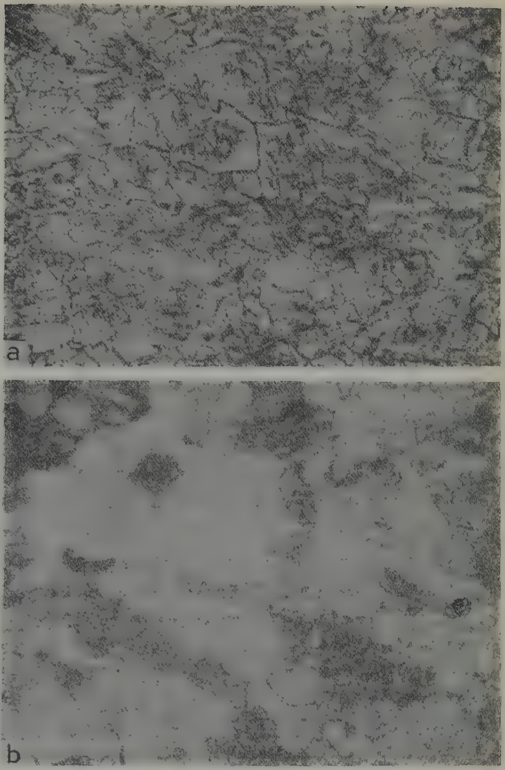

FIGURE 1. Texture of jadeite rock. Sp. 610/51, x13.

a - analyzer out, b - analyzer in

properties of the Polar Urals jadeite (Table 1) are very similar to those of jadeites from other localities, especially from the Balkhash region and Burma. All jadeites, as can be seen from Table 2, show variation in the content of all components and especially of CaO, MgO and Fe. Recalculations of the chemical analyses indicate that jadeite contains diopside and acmite molecules.

The crystallochemical formula of jadeite based on recalculation of chemical analysis (sp. 610, V.M. Nekrasova, analyst, IGEM laboratory) has the following form:

$$(Na_{0.94}Ca_{0.06})_{1.0}(Al_{0.88}Fe'''_{0.02}Ca_{0.03}Mg_{0.09})_{1.02}[Si_2O_6].$$

The slight excess of Ca in the mineral is evidently due to disseminated impurities. Jadeite occurs sparingly in nature. It is a component of omphacite, the characteristic pyroxene of eclogites, which may be considered as a mineral forming under high pressure. In a number of foreign laboratories, jadeite has been synthesized experimentally at pressures exceeding 10,000 atmospheres.

Table 1

X - Ray Powder Data for Jadeite

Jadeite described in this paper (sp. 610)		Jadeite after V. I. Mikeyev		Jadeite described in this paper (sp. 610)		Jadeite after V. I. Mikheyev	
I	dα	I	dα	I	dα	I	dα
2	6,200	1	6,240	7	1,498	—	—
3	5,46	—	—	7	1,480	6	1,475
5	4,32	4	4,353	6	1,433	1	1,437
9	3,25	1	3,302	10	1,363	7	1,353
9	3,12	1	3,146	7	1,297	3	1,300
10	2,91	10	2,938	4	1,282	—	—
10	2,83	7	2,841	4	1,268	3	1,274
10	2,49	9	2,497	9	1,241	3	1,239
10	2,40	6	2,421	2	1,216	3	1,217
7	2,20	4	2,224	7	1,200	—	—
7	2,15	4	2,127	4	1,167	1	1,174
7	2,06	4	2,075	7	1,143	—	—
7	1,973	4	1,983	4	1,133	2	1,130
2	1,894	1	1,897	3	1,104	1	1,106
3	1,766	2	1,772	3	1,079	1	1,082
2	1,733	—	—	7	1,064	1	1,072
5	1,684	2	1,690	4	1,045		
5	1,649	2	1,651	10	1,036	5	1,038
6	1,609	3	1,609	9	1,028	—	—
7	1,572	—	—	4	1,015	—	—
4	1,547	3	1,556	8	1,000	3	1,009

Note: commas represent decimal points.

E. Robertson and his associates [8] studied the reaction, nepheline + albite = 2 jadeite at T = 600° − 1200°C and P = 10,000 − 25,000 atm, and showed that jadeite forms predominantly at pressures near 20,000 atm. It is believed that below 15,000 atm jadeite occurs together with albite and nepheline and melts congruently at 25,000 atm. These data agree with the experimental results of L. Coes [6], who proved that jadeite forms at 900°C and 20,000 atm pressure.

However, in recent years, as a result of accumulated geological data and detailed studies of jadeite occurrences, a new concept of jadeite as a metamorphic mineral forming at low temperature and medium pressure has been widely used in foreign literature.

At present, only a few occurrences of jadeite rocks and jadeite-bearing veins are known.

At the Japanese locality [7], jadeite forms borders around albitite bodies in serpentinites. In the Omi district [5], jadeite rock is banded owing to alternation of white, blue and violet varieties with albite and albite-jadeite rocks. Jadeite is associated with albite, quartz, actinolite and analcime. It is supposed that albite and jadeite are primary minerals formed by intrusion of basic rest magma into dunite. In the classical laccoliths of Burma [10], intruded into serpentinites, as in Japan, jadeite is associated with albite, nepheline, an alkalic amphibole of the eckermannite type and glaucophane. The hypothesis that jadeite is formed by desilication of granitic magma under high pressure has been questioned by W. P. Roever, who believes that Burmese jadeite was formed by decomposition of albite as a result of regional metamorphism.

In California [4], jadeite is found in metagraywacke in paragenesis with glaucophane, lawsonite, quartz and albite.

On Celebes [9], albite-jadeite rocks are found in metamorphosed shales, quartzites, sandstones, spilites etc. Here, jadeite is associated with lawsonite, glaucophane, crossite, quartz and pumpellyite.

In the California and Celebes localities the formation of jadeite is related to decomposition of primary albite of the enclosing rocks into quartz and jadeite. The paragenesis of jadeite with glaucophane, lawsonite, quartz and pumpellyite suggests that the decomposition of albite occurred under conditions of low rank regional metamorphism corresponding to the glaucophane facies at a stable pressure of 3 to 5 thousand atmospheres.

Table 2

Chemical Composition and Optical Properties of Jadeite From Different Localities

Components	Polar Urals, sp. 610	Northern Balkhash region (1958)		California (1956)	Celebes (1955)	Burma (1950)	Japan	
							green	white
SiO_2	58,20	59,00	58,62	60,64	60,50	59,01	58,02	58,35
TiO_2	0,06	0,26	—	1,24	0,44	0,01	0,04	0,04
Al_2O_3	21,92	23,59	25,28	18,17	20,87	24,31	22,96	29,90
Fe_2O_3	0,94	1,25	0,20	3,68	3,15	0,35	0,77	0,36
FeO	0,09	0,27	—	0,53	0,93	0,03	0,18	0,08
MnO	Trace	0,02	—	0,07	—	0,02	0,01	—
MgO	1,72	1,04	0,48	1,09	0,47	0,58	1,70	0,78
CaO	2,46	1,32	0,78	2,13	0,67	0,77	1,58	0,98
Na_2O	14,13	11,77	14,54	11,36	13,03	14,37	12,38	12,35
K_2O	0,29	0,41	Trace	0,25	0,25	0,02	0,16	0,12
H_2O^+	0,50	0,59	0,82	0,78	0,15	0,06	0,87	1,24
H_2O^-	—	0,20	—	0,11	0,08	—	0,61	0,67
Li_2O	—	—	—	0,05	—	—	—	—
Total	100,31	99,72	100,72	100,10	100,54	100,03	99,28	99,37
2V	68—72	76	72	86	70—75	—	72—74	
$c\gamma Z$	38—42	36	36	—	40—50	—	33	
Ng	1,674	1,668	1,672	1,670	1,67	—	1,673	
β	1,668	—	—	1,663	—	—	1,663	
α	1,658	1,656	1,659	1,659	—	—	1,658	
$\gamma - \alpha$	0,016	0,012	0,013	0,012	0,012	—	0,015	
Sp. g.	3,14	—	—	3,28	—	—	—	

Note: Commas represent decimal points.

Jadeite was first discovered in the Soviet Union in the northwestern Balkhash region [3], where it is found in antigorite serpentinites separated from the enclosing rock by narrow borders of tremolite and tremolite-chlorite rocks. The jadeite rock at this locality is considered to be of hydrothermal-metasomatic origin, formed at the expense of leucocratic dikes in the ultrabasic intrusive.

At present only a very general statement can be made concerning the genesis of jadeite rock in the Polar Urals, for the occurrence has not been studied in detail. Although its occurrence is geologically similar to that in the northern Balkhash region, there is no basis for considering the Polar Urals jadeite as a hydrothermal-metasomatic alteration of leucocratic rocks. Plagioclase rocks, including albitites and also plagiogranites, are widespread in the ultrabasic rocks of the Polar Urals and locally they occur in the immediate neighborhood of jadeite rock, but jadeite has not been found in any of these rocks. On the other hand, there is a clear relationship between jadeite and diopside, whose metasomatic origin can hardly be questioned.

A.N. Zavaritskiy [1] related the formation of albitites and diopside rocks in the Ray-Iz peridotites to injection of pegmatoidal solutions desilicated by reaction with the injected rocks. This opinion is the most acceptable in explaining the origin of jadeite rock in the Polar Urals. The formation of diopside in some cases and of jadeite in others depended, probably, on the characteristics of the solutions and on temperature and pressure. The nature of feldspathic injections capable of penetrating hard rock through the finest cracks, the de-serpentization of olivine near the injections and the formation of enstatite-anorthite-diopside reaction zones suggest high temperature and pressure as the factors of injection metasomatism. The ultrabasic rocks, undersaturated in silica, provided a favorable medium in which variations in the concentration of silica in the solutions could alone cause formation of jadeite instead of albite.

Evidently under natural conditions jadeite rocks and jadeite-bearing rocks may form in different ways and the explanation of the origin of these rocks, rare in the Soviet Union, and interesting from both theoretical and practical points of view, must be the subject of further investigation.

REFERENCES

1. Zavaritskiy, A.N., Peridotitovyy massiv

Ray-Iz na Polyarnom Urale. izbr. tr., t. i. [RAY-IŽ, A PERIDOTITE MASSIF IN THE POLAR URALS. SELECTED WORKS, v. I]: Izd. Akad. Nauk SSSR, 1956.

2. Mikheyev, V.I., Rentgenometricheskiy opredelitel' mineralov. [X-RAY DETERMINATIVE TABLES FOR MINERALS]: Gosgeoltekhizdat, 1957.

3. Moskaleva, V.N., Zhadeitity Severnogo Pribalkhash'ya. [JADEITE ROCKS OF THE NORTHERN BALKHASH REGION]: Byull. nauchn.-tekhn. inform., no. 2, 1958.

4. Bloxam, T.W., Jadeite-bearing metagraywackes in California: Amer. Mineral., vol. 41, no. 5/6, 1956.

5. Chihara, K., Jadeite from Ōmi Niigata prefecture. Jubilee publication in the commemoration of Professor Fujimoto: Tokyo, 1958.

6. Coes, L., High pressure minerals: Amer. Ceramic Soc. J., v. 38, no. 8, 1955.

7. Iwao, S., Albitite and associated jadeite rock from Kotaki district, Japan: Geol. Surv., Japan, rep. no. 153, 1953.

8. Robertson, E. et al., Experimental determination of jadeite stability relations to 25,000 bars: Am. J. Sci., v. 255, no. 2, 1957.

9. Roever, W.P., Genesis of jadeite by low-grade metamorphism: Amer. J. Sci., v. 253, no. 5, 1955.

10. Yoder, H. The jadeite problem: Amer. J. Sci., v. 248, 1950.

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REVIEWS AND DISCUSSIONS

COMMENT ON THE BOOK: "TECTONICS AND HISTORY OF THE DEVELOPMENT OF THE CASPIAN DEPRESSION AND ADJACENT REGIONS IN CONNECTION WITH PETROLEUM AND GAS DEPOSITS"[1,2]

by

G. Ye. -A. Ayzendshtadt, S. N. Koltypin and N. K. Trifonov

At the end of 1958, the Gostoptekhizdat published a monograph on "Tectonics and history of the development of the Caspian depression and the adjacent regions in connection with petroleum and gas deposits" under the editorship of professors M. P. Kazakov and M. M. Charygin.

Omitting the question of the valuation and prospects of individual regions, we shall review here only the authors' data and conclusions which contradict the factual geological information on this territory.

In the beginning of the second chapter, "The characteristics of the facies and their thicknesses," it is proved that tectofacies analysis can be used in the salt dome region of the Caspian depression, and a reader unfamiliar with the region gets the impression that the authors of the monograph are the first to discover this possibility. Actually, it had been shown long before the publication of the monograph that sedimentation on a regional scale is not noticeably affected by the growth of salt domes. To be convinced of this, it is enough to glance through the articles published long ago and current reports in which all these questions have been answered on the basis of all available factual material and which contain isopach and facies maps as well as other data for large areas of the salt dome region. The same comment applies to the authors' conclusion concerning the conditions of formation of the salt domes, their intermittent growth and so forth.

It is impossible to agree with the authors' statement that "as a rule, the thicknesses of individual zones persist over large distances" (p. 23), for individual Mesozoic zones show considerable change in thickness from the northern and eastern margins of the Caspian depression towards its central and soithern parts.

This is particularly well illustrated by change in the thickness of some Upper Cretaceous zones in this direction. For example, the maximum thickness of the Inoceramus cardissoides zone on the North Emba domes is about 5 m, but in the South Emba region it it up to 25.5 m. This pattern applies also to other Upper Cretaceous zones of the Caspian depression.

It is not clear why the description of the region begins with the Upper Carboniferous. The Lower Carboniferous sections within the boundaries of the South Emba uplift were penetrated by drilling in 1953-1955, and Upper Devonian sections in 1956, and some of the data were published in 1954-1955 by N. A. Kalinin and A. L. Yanshin. The same criticism applies to the description of the Artinskian and Kungurian sections, which completely disregard the data from exploratory boreholes at Tukarakchan in the south of the South Emba region. Here the authors largely repeat the statements of V. P. Pnev, V. Ye. Ruzhentsev and others. On p. 44 there is a reference to a borehole in the village of Aznagul which reached Kungurian beds beneathe the Permo-Triassic sequence. In reality, exploratory borehole No. 2 (the borehole apparently referred to) stopped in the Permo-Triassic beds and did not and could not have reached the Kungurian beds, which lie here at a depth of 4000 m.

The diagram of distribution of facies complexes and thicknesses of the Kungurian strata is incorrect. In constructing this diagram the

[1]O knige "Tektonicheskoye stroyeniye i istoriya razvitiya Prikaspiyskoy vpadiny i smezhnykh oblastey v svyazi s voprosami neftegazonosnosti".

[2]By M.P. Kazakov, M.M. Charygin, R.I. Bykov, Yu.M. Vasil'yev, V.V. Znamenskiy and R.B. Seyful'-Mulyukov. Gostoptekhizdat, 1958.

authors did not take into consideration the data on the depths to the sub-salt zones known from seismic work and information on the volume of salts in the cores of the salt domes.

The data on the thickness of the Kungur beds shown on the diagram are random and do not reflect the tectonic conditions of sedimentation at that time.

From a description of the Permo-Triassic beds in the second chapter of the monograph we learn that "The time of accumulation of the redbeds in the Caspian depression embraces a vast period from the end of the Lower Permian to the Upper Triassic, inclusively" (p. 49).

It should be noted that redbeds have not been found in the Lower Permian strata of the region and that the Kungurian salt-bearing beds responsible for the formation of salt plugs cannot be called redbeds. The Lower Triassic strata include thick limestone beds besides the redbeds, but in the Upper Triassic section gray beds predominate and redbeds are very rare. Thick gray beds occur also in the Tatarian stage; but as for the Lower Permian rocks, they have not been penetrated by boreholes anywhere in the areas between the salt domes and there is no reason to refer them as a whole to redbeds, for they may include sediments of other types as well.

Farther on, the authors' view on this subject leads them to a number of incorrect paleogeographic and paleotectonic reconstructions.

The authors' concept of conformity between the Lower Triassic and the underlying beds (p. 51) in the central part of the Caspian depression also is erroneous. Actually, these beds are separated by an angular unconformity. This section, like most of the others, is based not on original work by the authors but exclusively on the published data. At present there is sufficient material for separating Permian and Triassic deposits.

The authors' paleotectonic reconstructions based on an analysis of thicknesses of the permo-Triassic beds invite serious objections. If they really used seismic data, scant though they are for the Caspian depression except for the South Emba and Aktyubinsk Priura'lye areas, how could they have deduced the enormous area of diminished thickness of the Permo-Triassic deposits (less than 500-700 m) in the northern part of the depression?

This is not at all what the available seismic data suggest. Evidently Kazakov, Charygin and others consider that the presence of a gravity high in the region is sufficient to indicate a zone of diminished thickness. The generally known data on the regional high in the western part of the South Emba area fully exclude the possibility of such primitive analysis of gravimetric data.

The Jurassic deposits are characterized on the basis of rather obsolete published data without any serious revision of the material by the authors of the monograph, and it is difficult to find here any new ideas or constructions. But even the published data are not fully utilized; for example, there is no reference to a very interesting work by the coal geologist K. F. Abramovich. Here again, as in the case of the Permo-Triassic beds, one is astonished by the boldness with which Vasil'yev, Kazakov and Charygin draw an isopach map for different areas without any factual data.

Serious objections are aroused by the map of thicknesses and facies complexes in the Middle Jurassic. Partly because of the lack of factual material, but mainly because of the use of incomplete thicknesses (reduced by erosion) of different formations, the distribution of downwarps and upwarps, the boundaries of the facies complexes and even ancient shorelines are completely undocumented for a large part of the region. The main point is, however, that because the Bajocian and Bathonian stages are not differentiated (and they can be now) sedimentary rocks of different ages are correlated.

This interpretation of material has led to the separation within the South Emba Middle Jurassic deposits of two different lithological complexes, the argillaceous complex (in the part of the region adjacent to the sea, the area between Gur'yev and Dossor, Karaton and Kulsarami) and the coal-bearing argillaceous complex (the rest of the South Emba region).

This change in lithology is not confirmed by facts. The information on the thicknesses of the Middle Jurassic of Mangyshlak (p. 85) are given after S. N. Alekseychik, while for some reason the most recent data of the All-Union Aerogeological organization and of the All-Union Petroleum Institute are disregarded.

The description of the Cretaceous deposits begins with the obviously obsolete information on the Valanginian stage. The distribution of these rather thick beds (about 100 m) is known not only in the Baychunas and Tentyaksor area but also to the north of Dossor and Makat, in the Ungar area and elsewhere (for example, in Akatkul in the extreme south of the region). Using work published before 1943, the authors erroneously refer a Neocomian sandstone zone to the Hauterivian while in reality it is Barremian. And for some reason or other they rename this zone the "Sandy formation" (p. 98).

The Lower Cretaceous of Mangyshlak is described after the old work of Alekseychik, although more complete information on the

different parts of Mangyshlak is given in the works of V. V. Mokrinskiy and the VNIGRI geologists. The work of N. Yu. Klycheva and other studies based on material from boreholes pass unnoticed in the monograph. On the facies map of individual Cretaceous stages the separation of the facies complexes and their boundaries are not documented at all. A particularly good example of this is the separation in the South Emba region (see outline facies and isopach map of the Albian deposits in the Caspian depression, appendix 11) of two lithological complexes: argillaceous (eastern part of South Emba) and arenaceous-argillaceous (the rest of the region). An extensive investigation including electric logging made earlier (mainly by the geologists of the Central scientific laboratory of the "Kazakhstanneft'" association and VNIGRI) showed that in reality there is no facies change in the sediments of this stage. The lower and middle Albian beds are mainly clays and the upper Albian rocks are sandstones.

The separation of several facies zones in the Santonian is also incorrect. A study of a drill core and electric logs indicates that the same type of sediment occurs throughout the area. It is not possible, either, to speak of the facies changes in Campanian sections within the South Emba region. Actually, marls are present everywhere. The thickness of the Campanian and lower Maestrichtian (Campanian as understood by Kazakov and others) is diminished. The maximum thickness of these stratigraphic complexes is not 140 m but 200 m and more (for example, in Tentyaksor).

On the outline facies and isopach map of the Maestrichtian stage a large part of the Uralo-Emba region is shown as lacking sediments of this stage, which is untrue. In general the thickness of the upper Maestrichtian (Maestrichtian according to Yu. M. Vasil'yev, Kazakov and others) is diminished. It is impossible to agree with the authors' opinion that there is a sharp contact between the Paleogene and the Danian stage (p. 154). Nowhere in the South Emba region has such contact been observed, and on Mangyshlak the change from the Danian stage to the Paleogene is not everywhere definite.

As has already been shown the thicknesses of the different Mesozoic stratigraphic units were incorrectly determined by the authors at many points. This is especially evident on the Cretaceous facies and isopach maps (appendices 9 - 19).

It must be added to the facts cited earlier that the maximum thickness of the Upper Cretaceous in the eastern part of the Caspian depression is not 439 but over 540-550 m. Upper Cretaceous strata with this thickness were penetrated by a number of boreholes in the South Emba region (for example, borehole 13 at Karaton) long before the publication of the monograph. It should be pointed out also that the maximum thickness of the Neocomian in the same area is not 440-480 m (appendix 9) but over 520-530 m.

The maximum thickness of the Albian formations in the eastern part of the Caspian depression lying to the north of lat. 47° is not 350-380 m but 460-490 m (see sections from borehole 128 at Yuzhnyy Koshkar and others).

Similar errors were made in constructing the isopach maps of other subdivisions of the Cretaceous. The list of errors may be extended considerably, and it follows that the downwarped and upwarped zones shown on the isopach maps of different Cretaceous stratigraphic units either do not exist at all or are incorrectly outlined.

On the correlation diagrams (appendix 14), Turonian and Coniacian stages of Mangyshlak are shown entirely as carbonate facies, while in reality the larger part of the Turonian deposits there is arenaceous. The thickness of the Senomanian on Mangyshlak, according to the authors' data, varies from 30 to 70 m, while actually its maximum thickness reaches 140 m.

Similar mistakes occur in the description of the Maestrichtian of Mangyshlak, whose thickness reaches 250 m locally, while the monograph gives 100 m for its maximum thickness. The thickness of the Danian beds is given as 80 m, but actually it is 130 m. The total thickness of the Upper Cretaceous deposits on Mangyshlak is well known to be up to 800 m and not 392 m as given in appendix 19.

The facies and isopach map of the Paleogene deposits of the Caspian depression is also incorrect (appendix 20). In the authors' opinion, in the eastern part of the Caspian depression Paleogene sediments are continuous to the west of the 53d meridian and to the south of the 47th parallel. It is difficult to accept this statement. It is apparent from the data on the thoroughly investigated South Emba region that the Paleogene sediments are not continuous in the area to the west of the 53d meridian (between the 53d meridian and the Ural River valley) nor in the area between meridians 53-54 and 46-47 (see South Emba geological-tectonic map, 1:100,000).

On page 161 (Figure 20) the Paleogene correlation chart for Mangyshlak does not show the detailed data of Ye. V. Liverovskaya and N. F. Kuznetsova, and on p. 173 (Figure 21) in connection with the Neogene chart the authors refer to the obsolete work of V. P. Kolesnikov.

In appendix 22 the thicknesses of the Apsheron deposits in the Novobogatinsk region are shown as not exceeding 300 m, but in reality they are much thicker, 1,000 m and more. The great thickness of the Tertiary strata in the southern maritime zone of the Caspian depression is not a result of "inexact interpretation of seismic

data" as stated on p. 186 by Vasil'yev and Kazakov in criticism of Nevolin's work. These seismic data have been checked and confirmed by drilling in the Novobogatinsk region and completely contradict the authors' idea that an uplift exists in this region.

In the beginning of chapter IV, "Tectonics and history of the development of the Caspian depression," a description is given of the tectonic schemes proposed for the Caspian depression at different times, from N. N. Tikhonovich's scheme of 1924 to the latest one by A. L. Yanshin. In solving the problem of the Hercynids in the southeast of the Caspian depression and of the southwest bend of the Urals, the authors favor the idea of the existence of a Hercynian folded structure in the south of the region. Although debatable points are avoided as much as possible in this review, it must be mentioned that three or four years have elapsed since the monograph was prepared for the press and yet deep drilling in this region has disclosed no convincing proofs of the existence of any folded structures in the area of the South Emba gravity maximum. As for the gravimetric data, they show, as has been pointed out by Yanshin, an absence of direct relation between the Urals and the South Emba uplift. In defending their concept of a foredeep in the South Emba region, the authors cite incorrect data on the thickness of the Lower Carboniferous (over 2000 m) and the entire Carboniferous (over 2500 m). Actually, in this region only 250 m of the Upper Carboniferous strata, 443 m of the Middle Carboniferous and 992 m of the Lower Carboniferous strata, or altogether only 1685 m, have been penetrated by drilling. Even if it is assumed that parts of the section were missed by the boreholes, the thickness of the Carboniferous deposits cannot exceed 2000 m.

The description of Mesozoic and Cenozoic structures in the marginal parts of the Caspian depression is based on the already reviewed lithofacies maps. As was shown above, a considerable part of the structures (downwarps, uplifts) is poorly documented because of use of inaccurate data on the thicknesses and composition of the section, and therefore all subsequent constructions and conclusions of the authors concerning the history of the structures are also unsupported by factual material. The authors' idea that the growth of the salt domes was most intensive in pre-Jurassic and pre-Akchagylian times (p. 285) is incorrect: it was equally intensive in the Cretaceous. The diagrammatic geologic sections across the Caspian depression (appendix 32) in which the Mesozoic deposits are shown as almost undeformed are unconvincing. Paradoxical as it sounds, if the sections drawn by the authors of the monograph are accepted as correct, then there should be no salt domes in the salt dome region. Moreover, all this is evident contradiction to what is shown in appendix 35, as well, of course, as with reality.

The criticisms cited above make it impossible for the reviewer to accept the favorable appraisal of the monograph given by K. I. Satpayev in issue No. 4 of the journal, "Geologiya nefti i gaza" for 1959.

"GEOLOGY OF THE ARKANSAS BAUXITE REGION," A MONOGRAPH BY M. GORDON, J. TRACY AND M. ELLIS[3,4]

by

G. I. Bushinskiy

The Arkansas region contains the largest bauxite reserves in the U. S. A. The monograph summarizes the results of many years of geological and exploratory work, describes and classifies bauxite deposits, and discusses the mineralogy, petrography and geology of bauxites and their origin and distribution on the surface of the early Eocene land. The monograph contains 268 pages of text and 33 maps and charts, of which 28 are in color.

Some information on the Arkansas bauxites was published by the reviewer in the book: Bauxites, their mineralogy and origin, 1958, pp. 209-214 (ed. Academy of Sciences, USSR). Here, only some additional data will be presented.

Bauxite was discovered in Arkansas in 1887 and its exploitation began in 1898. From that time on, ownership of the deposits changed hands frequently, and altogether 61 companies have participated in their exploitation of which six were still active in 1949. Altogether there are 176 quarries and mines, of which 14, including 4 underground workings, were active in 1949.

A systematic geological study of the region by the U. S. Geological Survey and U. S. Bureau of Mines began in 1941. These organizations summarized existing geological data, bored 6,932 holes and made geophysical surveys to determine bedrock relief beneath the bauxite deposits.

Exploratory holes were drilled 305 m apart on a triangular grid (wildcat drilling). Such a grid could not miss deposits with more than 50,000 tons of ore. Over the bauxite-bearing areas, a finer network was used, with holes

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[3] O monografii M. Gordona, Dzh. Tresi i M. Ellisa "Geologiya Arkanzasskogo baksitovogo rayona".

[4] Geology of the Arkansas Bauxite region. By Mackenzie Gordon, Joshua I. Tracy and Miller W. Ellis. U.S. Geological Survey, Professional Paper 299, 1958, Washington.

61 m and 305 m apart. The drill holes were continued to bedrock. In delimiting bauxite deposits, the minimum workable thickness was taken as 2.5 m (for underground mining) and minimum alumina content as 32%. The tenor of ore was determined by subtracting the percentage of SiO_2 x 1.1 from the percentage of alumina. Considering that in war time even low grade deposits might be useful, the U.S. Bureau of Mines took 1.5 m as the minimum thickness of bauxite and 24% as the minimum alumina content.

The authors define bauxite as a rock composed of gibbsite, kaolinite, siderite and other minerals, with over 50% gibbsite and over 24% alumina. Rocks containing from 24 to 32% available alumina are called high silica bauxites and those containing over 10% Fe_2O_3 are called high iron bauxites.

The region is underlain by gently folded Paleozoic strata. In the Upper Cretaceous three nepheline syenite massifs were emplaced in these strata. The marine arenaceous sandstones and shales of the Midway formation 0 to 600 m in thickness (Paleocene) lie unconformably on the Paleozoic beds and on the lower parts of nepheline syenite massifs. The Paleocene beds are covered, in their turn, by the continental deposits of the Wilcox group (Lower Eocene) reaching 300 m in thickness and abutting against nepheline syenite hills. The lower member of this group, known as the Berger formation, contains bodies of bauxite. It is from 0 to 100 m thick and is composed of greenish-gray and bluish-gray silty and, less commonly, bauxitic kaolinite clays and greenish-gray fine-grained sandstones alternating with black lignitic and brown carbonate clays and siderite lenses. Deposits of brown bauxite border nepheline syenite outcrops and penetrate in tongues into the Berger formation where they pass into detrital kaolinitic claystone facies representing talus material derived from the bauxites.

Most bauxites are hard, brittle, nonplastic, light-brown, locally pink or red rocks. The lighter colors are characteristic of the low grade bauxites; white, of pure gibbsite. The structure of bauxite is "granitic," pisolitic or aphanitic (clay-like bauxites); specific gravity is 2.4 – 3.0; porosity, 30 – 40%. The "granitic" bauxite retains the texture of nepheline syenite, in which the feldspars have been replaced by gibbsite, and sphene by leucoxene. The groundmass of this variety of bauxite is brown or red. It is a very porous rock, and the miners call it sponge ore. "Granitic" bauxite overlies kaolinized nepheline syenite on the upper slopes of nepheline syenite hills, forming a layer 2 to 3 m in thickness with irregular lower and upper boundaries.

Pisolitic bauxite is the most abundant. The pisolites, with characteristic network of radial gibbsite-filled cracks, are from 3 to 20 mm in diameter and are set in a hard or soft groundmass. The pisolites contain 60 – 70% Al_2O_3, 6 – 10% Fe_2O_3, 2 – 3% TiO_2, 2 – 3.5% SiO_2 and 15 – 32% H_2O; and the groundmass contains 57 – 61% Al_2O_3, 2 – 5% Fe_2O_3, 3.6 – 4.2% TiO_2, and 32% H_2O. Boehmite occurs in water-poor bauxites. Some pisolites are light-colored and soft or hollow. Their distribution is irregular; in some places they are abundant, in others, scarce. The pisolitic variety of bauxite known as the "bird's eye ore" overlies "granitic" bauxite and is characteristic of the residual desposits on the upper slopes. A pisolite fragment is present in bauxite shown in Figure 15-A, and this makes it doubtful that the bauxite is residual as supposed by the authors. Very often this variety of bauxite has vermiform structure and sometimes it is cellular and slag-like.

Although a considerable part of the ore is of sedimentary origin, the diagnostic criteria indicating this are not many. Fragments and blocks of granitic or pisolitic bauxite are common in bauxite, layered clay or sand. In the Saline district high grade ore of this type consists of well rounded fragments of bauxite enclosed in fine-grained material without visible stratification. This conglomeratic ore is outwardly similar to the concretionary bauxites found in the middle and, locally, in the upper parts of the upland bauxite deposits. Sometimes the pisolites are well sorted according to size in successive layers, and locally cross-bedding is well developed.

The mineralogy of the bauxites has been thoroughly investigated, but a number of details still remain unclear. The bauxites are composed of gibbsite, while boehmite occurs only occasionally in the chert-like magnetic pisolites. The impurities are kaolinite, halloysite, siderite, hematite, geothite, magnetite (and maghemite?), pyrite, ilmenite, sphene, anatase (leucoxene), rutile, rarely chamosite, chlorite, zircon, garnet and kyanite. Gibbsite is present in two forms – crystalline or microcrystalline and cryptocrystalline or amorphous. The first form occurs as pseudomorphs after feldspar in the granitic bauxite and fills cracks and pores in the pisolites and the matrix of pisolitic bauxite. The second type of gibbsite is the principal one. Siderite occurs in crystals in geodes and cracks, in small spherulites and in masses replacing bauxite and containing relict structures.

Nomograms for determination of the mineral composition of bauxites from chemical analyses are given.

The distribution, form and quality of the deposits is determined by three very important factors: 1) the nature of the parent rocks, 2) the pre-ore relief and 3) erosion and deposition during bauxite accumulation in the Wilcox time.

All bauxite deposits lie on outcrops of nepheline syenite or near them. The outcrops of other pre-ore rocks, although they show signs of kaolinization, are not accompanied by bauxites. There are three main outcrops or hills of nepheline syenite: Pulaski, Bryant and Saline. The diameter of the Bryant outcrop is about 3 km and of the other two, between 8 and 9 km. The 1:31, 680 contour map of the bauxite-bearing formation shows that the high level bauxites lie about 180 m above the low-level bauxites and that the distance between them is 3 km, so that the slope on which they lie is 60 m per km.

Most bauxite deposits lie on the slopes of the nepheline syenite hills extending from just below the top (the top deposits have been eroded) to the base. A few deposits occur at the base of the outcrops, but usually not more than 1 km away from them. Several small deposits have been found 7 to 8 km east of the base of Pulaski hill. As can be seen from the 1:3000 map, there is no strict relationship between the details of the pre-ore relief and the bauxite deposits, which lie on gentle slopes, in gullies or valleys and at the foot of the nepheline syenite outcrops. Unlike the Tikhvin bauxites, the Arkansas bauxites lying on gully edges have higher alumine content than those in the gullies.

As a result of ancient erosion and reworking, some bauxites were deposited as talus at the base of the hills and in the mouths of gullies as alluvial cones. Because of the steepness of relief, bauxite was transported not only by water but also by slides, slumps and mud flows.

In plan, the bauxite deposits are usually irregular, amoeba-like, and enclose barren areas. They are usually 0. 2 - 1 km, rarely 2 - 3 km across, range from 3 to 12 m with a maximum of 18 m in thickness, and contain 45. 5% Al_2O_3.

Kaolinization is the most intensively developed secondary process. Some bauxite bodies are cut by networks of cracks filled with kaolinite, which forms veinlets and veins from a few millimeters to 1 - 2 m thick and replaces bauxite. Locally the veins are so frequent that they constitute the main part of the rock, with bauxite relicts occupying spaces in the network.

From 1916 to 1940 the production of bauxite was about 300 thousand tons annually, in 1943 it reached 7 million tons, and in the post-war years has been maintained at 1. 2 million tons per year.

The freshly mined bauxite contains from 5 to 20% of moisture or 15% on the average. It is usually dried in rotating kilns at 100 - 140°C. For abrasives and refractories the bauxite is heated at the temperature of about 600°C, and for petroleum refining it is activated at about 500°C.

The reserves of moist ore in bauxite beds over 1. 5 m thick were estimated in 1950. The ores were classified according to the average alumina and silica content into three kinds (in %):

Kind	Al_2O_3	SiO_2	Reserves in millions, tons
1	59	5	6
2	52	10	48,9
3	50	9	88,9

Almost all this reserve has been explored (measured and indicated) and only 2. 5 million tons are regarded as unproved.

The following remarks may be made in conclusion. The monograph under review is the most complete and many-sided of all the monographs on bauxite published in different countries. The map of relief beneath the ore and the geologic sections illustrate well the regularities of distribution of bauxite deposits and provide information of their size and form. The photographs and photomicrographs show structures and replacement processes.

The monograph does not contain full chemical analyses nor does it describe ore types and the variation in their composition vertically, areally and along the profiles. The origin of fragmental clay underlying "granitic" bauxite is not clear. The bauxite is considered metasomatic-residual and should not have any fragmental clays beneath it.

The authors mention the presence of boehmite in black pisolites. It is not impossible that by analogy with Soviet gibbsitic bauxites they also contain corundum.

Siderite is present in all buried deposits and has a spotty distribution, but the proportion of ferrous and ferric iron in ferruginous bauxites it not made clear.

The bauxite deposits gradually pass, laterally and vertically, into high-alumina clays. The complex of clays and bauxites is usually called the bauxite-kaolin zone and is a facies of the Berger formation. This facies borders the nepheline syenite outcrops and is from 20 to 25 m in thickness. The main admixture in the kaolinite clays is siderite, locally oxidized. On the map of distribution of high-alumina clays in the Pulaski district, showing isopachs and relief, it is shown quite clearly that these clays border the eastern and southern base of the nepheline syenite hill. The width of the clay border is 1 to 1. 5 km and the slope of the hill is 50 m per km. All bauxite deposits lie within

this band but are concentrated near its upper edge, i.e., near the nepheline syenite outcrops. The structural, petrographic and chemical gradations from bauxites to the high-alumina clays are not made sufficiently clear.

The discussion of the origin of sedimentary bauxites adds considerable interest to the monograph. Their position on quite steep slopes and the abundance of fragmental material testify to the accumulation of bauxites by the action of water and gravity, leaving little room for hypotheses of chemical transfer of alumina.

COMMENT ON THE ARTICLE BY L. A. ROSSOVSKIY, A. I. SHOSTATSKIY AND L. S. ZIL'BERFARB: "CERTAIN IDEAS IN K. A. VLASOV'S WORKS AND THEIR ROLE IN THE SEARCH FOR AND VALUATION OF RARE METAL PEGMATITES" [5]

by

A.A. Beus

The article by L.A. Rossovskiy, A.I. Shostatskiy and L.S. Zil'berfarb published in No. 11 of Izvestiya for 1959 criticizes K.A. Vlasov's ideas on the characteristics, structure and composition of rare metal pegmatites [6, 7, 8, 9], and presents an allegedly new view of albitization and related rare metal mineralization in undifferentiated pegmatites. The authors criticize Vlasov's ideas from the point of view of their applicability to the search for rare metal pegmatites.

Their criticism is not based on facts and reveals a superficial knowledge of the literature on pegmatites. Not one of the ideas expressed by the authors is new, and their critical comments betray ignorance of the history of the exploitation of the rare metal pegmatites and slight knowledge of economic deposits of rare elements in pegmatites and the requirements these deposits must satisfy.

At every stage of the development of an economic mineral deposit the valuation of the deposit is determined first of all by the demand of industry for the given mineral. Valuation criteria are never constant but change with the demand of industry for a certain quality of mineral raw material. This can be illustrated very well by deposits of rare elements, for with the swift technological developments of recent years, the demand for these elements has undergone a particularly sharp change. Let us take beryllium, frequently mentioned by the authors, as an example. Until very recently, world industry used large beryl crystals from zoned pegmatites. In this connection, Vlasov's classification published 14 years ago has played and still plays an important positive role in the investigation and exploitation of rare metal pegmatites of the USSR.

It should not be forgotten in an objective appraisal of this classification that in the capitalist countries differentiated replacement pegmatites carrying rare metals provide 90% of beryl concentrate and 100% of tantalite production. The beryl concentrate from zoned pegmatites obtained by sorting without any special kind of beneficiation is still the cheapest source of beryllium.

However, during the last decade a sharp worldwide increase in the demand for beryllium ore has arisen and it is clear that in the very near future cheap coarsely crystallized ores will not be able to satisfy the growing demand of industry. It is for this reason that a number of experts on deposits of rare elements (including the writer) have been directing the efforts of our geologists in the search not only for deposits of coarsely crystallized beryl but also for deposits of finely crystallized beryl ores associated with various groups of replacement pegmatites and greisen [1, 3, 4].

It has become necessary to develop and augment the established prospecting criteria, and this has been done in a number of recently published works [1, 3, 4, 10]. Naturally, these additions in no way diminish the importance of searching for economic deposits of easily and cheaply exploited beryl and tantalite ores found in well differentiated replacement pegmatites.

It is unfortunate that no deposits of rare metals in zoned replacement pegmatites have been found in the Pamirs, but this is no justification for discounting large economic deposits of this type in other parts of the world.

It should be noted that not a single deposit of finely crystallized beryl in albitized pegmatites is being exploited anywhere at present; but under favorable economic conditions such deposits, if beryllium oxide content is high (over 0.05%) and the reserves considerable (over 1000 tons BeO), should soon become of practical importance.

Turning to tantalum, it should be mentioned that although tantalite as a mineral may be found in any strongly albitized pegmatite [11], economic deposits with high tantalum pentoxide content are known at present only in zoned, strongly replaced pegmatites.

Equally one-sided is the authors' criticism of Vlasov's opinion that massive crystalline rocks favor localization of large pegmatite deposits. It is to be regretted that the authors of the article do not know that the largest pegmatite deposits of lithium, beryllium, cesium and

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[5] Po povodu stat'i L.A. Rossovskogo, A.I. Shostatskogo i L.S. Zil'berfarba "O nekotorykh polozheniyakh v rabotakh K.A. Vlasova i ikh roli pri poiskakh i otsenke redkometal'nykh pegmatitov".

in part of tantalum in different parts of the world are related to pegmatites occupying fractures in basic rocks. This naturally, does not exclude the possibility that economic pegmatite deposits of rare elements may be found (no one has ever denied this). However, the assertion that Vlasov's opinion "is contrary to observed facts" only betrays ignorance of pegmatite deposits.

The critics should be advised that, in future, judgments of the applicability of this or that prospecting criterion should be made only after analysis of extensive material on existing economic deposits of different regions and not on the basis of study of a limited number of pegmatites of unproved economic value.

In their conclusion, Rossovskiy, Shostatskiy and Zil'berfarb made a number of unfounded remarks concerning the author of this note.

One cannot judge of Beus' views on the origin of replacement pegmatites and the geochemical relation between beryllium concentration and the process of replacement by his book, "Beryllium" [1] (valuation of deposits during prospecting and exploration), in which genetic questions are not touched upon at all. These questions were discussed by myself in the paper on "Geochemistry of beryllium in granite pegmatites" published in 1957 [2]. If the authors of the critical article were familiar with this paper, perhaps they would not have distroted my views on the origin of replacement pegmatites. If they had read the above mentioned book, "Beryllium", more attentively and had taken the trouble of acquainting themselves with the somewhat later instructions on prospecting for beryllium, tantalum and niobium deposits [3], it is possible that they would not have made the incorrrct statement that the "medium-grained replaced pegmatites with fine-grained aggregates of rare metal minerals including beryl crystals invisible to the naked eye are not discussed by Beus at all."

Rossovskiy et al., could have found information on the occurrence of finely crystalline beryl in the albitized zone of replaced muscovite-albite pegmatites in "Beryllium" (p. 68). It is mentioned repeatedly in this book that albitization is an important prospecting clue independent of the degree of differentiation of a pegmatite (pp. 68, 112, 116, etc.). In the instructions for prospecting for beryllium, tantalum and niobium published in 1957 [3], it is stated quite definitely that in economic beryl deposits in replaced muscovite-albite pegmatites up to 70% of beryl occurs in small crystals requiring special concentration methods (pp. 23, 24). And there is the following statement concerning valuation of albitized beryl-bearing pegmatites in the handbook designed for exploration geologists and prospectors: "At the same time the replaced albitized pegmatites must be appraised by the degree of their albitization. In evaluating albitized pegmatites, texture is not significant. It should be noted that all large economic beryl deposits in pegmatites are found in albitized pegmatites and this in itself indicates that albitization is the most important prospecting criterion" [4, p. 21].

It should be noted in conclusion that Vlasov's statements [5-8] (if correctly used, of course) and Beus' recommendations [1, 2, 3, 4] urge geologists to look precisely for replaced rare metal pegmatites. It is difficult to say, therefore, how Rossovskiy, Shostatskiy and Zil'berfarb arrived at the completely incorrect conclusion that Vlasov's statements and Beus' recommendations apply only to unreplaced beryl-muscovite pegmatites. This can be explained only by inadequate knowledge of the literature and factual material relevant to the problem.

Finally, the authors should be urged to give a detailed description of the pegmatites studied by them, for they are still very little known. There is no doubt that if they succeed in establishing criteria to be used in the search for economic deposits of rare metals in pegmatites which differ from the existing ones, these criteria will be gratefully accepted by our geologists working in this field.

REFERENCES

1. Beus, A.A., Berilliy. Otsenka mestorozhdeniy pri poiskakh i razvedkakh [BERYLLIUM. EVALUATION OF DEPOSITS IN EXPLORATION AND PROSPECTING]: Gosgeoltekhizdat, 1956.

2. Beus, A.A., K geokhimii berilliya v granitnykh pegmatitakh. [ON THE GEOCHEMISTRY OF BERYLLIUM IN GRANITIC PEGMATITES]: Izv. Akad. Nauk SSSR, ser. geol., no. 8, 1957.

3. Beus, A.A., M.D. Britayev, and N.A. Grechukhin, Metodicheskiye ukazaniya po proizvodstvu geologo-razvedochnykh rabot, vyp. 2. Razvedka mestorozhdeniy berilliya, tantala i niobiya. [GUIDLINES FOR GEOLOGICAL PROSPECTING OPERATIONS, No. 2. PROSPECTING DEPOSITS OF BERYLLIUM, TANTALUM, AND NIOBIUM]: Geogeoltekhizdat, 1957.

4. Beus, A.A., Trebovaniya promyshlennosti k kachestvu mineral'nogo syr'ya. Berilliy, vyp. 36. [INDUSTRIAL REQUIREMENTS FOR QUALITY IN MINERAL RAW MATERIALS. BERYLLIUM, No. 36]: Gosgeoltekhizdat, 1959.

5. Vlasov, K.A., Teksturno-geneticheskaya klassifikatsiya granitnykh pegmatitov. [STRUCTURAL-GENETIC CLASSIFICATION OF GRANITIC PEGMATITES]: Dokl. Akad. Nauk SSSR, nov. ser., t. 53, no. 9, 1946

6. Vlasov, K.A., K voprosu o genezise pegmatitov. [ON THE GENESIS OF PEGMATITES]: Dokl. Akad. Nauk SSSR, nov. ser., t. 78, no. 2, 1955.

7. Vlasov, K.A., Teksturno-parageneticheskaya klassifikatsiya granitnykh pegmatitov. [STRUCTURAL-PARAGENETIC CLASSIFICATION OF GRANITIC PEGMATITES]: Izv. Akad. Nauk SSSR, ser. geol., no. 2, 1952.

8. Vlasov, K.A., Genezis redkometal'nykh granitnykh pegmatitov. [GENESIS OF RARE-EARTH GRANITIC PEGMATITES]: Izv. Akad. Nauk SSSR, ser. geol., no. 5, 1955.

9. Vlasov, K.A., Faktory obrazovaniya razlichnykh tipov redkometal'nykh granitnykh pegmatitov. [FACTORS IN THE FORMATION OF VARIOUS TYPES OF RARE-EARTH PEGMATITES]: Izv. Akad. Nauk SSSR, ser. geol., no. 1, 1956.

10. Ginzburg, A.I., O nekotorykh osobennostyakh spodumenovykh mestorozhdeniy. [CERTAIN CHARACTERISTICS OF SPODUMENIC DEPOSITS]: Razvedka nedr, no. 1, 1950.

11. Ginzburg, A.I., O nekotorykh osobennostyakh geokhimii tantala i tipakh tantalovogo orudeneniya. [CERTAIN FEATURES OF THE GEOCHEMISTRY OF TANTALUM AND TYPES OF TANTALUM MINERALIZATION]: Geokhimiya, no. 3, 1956.

BIBLIOGRAPHY

LITERATURE ON GEOLOGY RECEIVED BY THE LIBRARY OF THE DEPARTMENT OF GEOLOGICAL AND GEOGRAPHICAL SCIENCES OF THE ACADEMY OF SCIENCES OF THE U.S.S.R IN DECEMBER 1959

A. Articles in Periodicals

GEOLOGY

1. Antropov, P. Ya., Nekotoryye zadachi geologicheskoy sluzhby v svete resheniy iyun'skogo plenuma TsK KPSS. [CERTAIN PROBLEMS FACING GEOLOGICAL SERVICE IN THE LIGHT OF THE RESOLUTIONS PASSED BY THE JUNE MEETING OF TsK KPSS]: Sov. Geol., no. 10.

2. Aristov, V.V. and F.P. Krendelev, Tektonicheskiye gal'ki v zonakh drobleniya Karamyshevskogo mestorozhdeniya (Rudnyy Altay). [TECTONIC PEBBLES IN THE FRACTURED ZONES OF THE KARAMYSHEV ORE DEPOSIT (RUDNYY ALTAY)]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 9.

3. Borukayev, R.A. and G.F. Lyapichev, K stratigrafii dokembriya Tsentral'nogo i Yuzhnogo Kazakhstana. [PRECAMBRIAN STRATIGRAPHY OF CENTRAL AND SOUTHERN KAZAKHSTAN]: Izvestiya, Akad. Nauk SSSR, ser. geol., vyp. 2(35).

4. Velikovskaya, Ye.M., K voprosu o pliotsenovom olednenii Osetinskoy ravniny. [THE PROBLEM OF PLIOCENE GLACIATION IN THE OSET' VALLEY]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 9.

5. Vlasov, N.G. and A.D. Miklukho-Maklay, Novyye dannyye po stratigrafi i kamennougol'nykh otlozheniy Yugo-Zapadnogo Darvaza. [NEW DATA ON CARBONIFEROUS STRATIGRAPHY OF SOUTHWESTERN DARVAZ]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

6. Vlasov, N.G. and A.D. Miklukho-Maklay, Novyye dannyye po stratigrafii permskikh otlozheniy Yugo-Zapadnogo Darvaza. [NEW DATA ON PERMIAN STRATIGRAPHY OF SOUTHWESTERN DARVAZ]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

7. Gerasimov, I.P., L.P. Serebryannyy and N.S. Chebotareva, Antropogen (pleystotsen) Severnoy Yevropy i yego stratigraficheskiye komponenty. [THE ANTHROPOGENE (PLEISTOCENE) OF NORTHERN EUROPE AND ITS STRATIGRAPHIC SUBDIVISIONS]: Izvestiya, Akad. Nauk SSSR, ser. geogr., no. 6.

8. Glushkova, M.I., Osnovnyye cherty orografii i skhema geomorphologicheskogo deleniya yuga Kirgizii. [MAIN FEATURES OF OROGRAPHY AND GEOMORPHOLOGICAL SUBDIVISIONS OF SOUTH KIRGIZIYA]: Izv., Akad. Nauk KirgSSR, ser. yestestv. i tekhn. nauk, t. 1, vyp. 2.

9. Derbikov, I.V. and Ye.I. Ben'ko, Tektonika mezo-kaynozoyskikh otlozheniy yuzhnoy chasti Zapadno-Sibirskoy nizmennosti v svete variatsionnogo analiza geologo-geograficheskikh dannykh. [TECTONICS OF THE MESOZOIC-CENOZOIC DEPOSITS OF THE SOUTHERN PART OF THE WEST SIBERIAN PLAIN IN THE LIGHT OF VARIATION ANALYSIS OF GEOLOGIC-GEOGRAPHIC DATA]: Sov. geol., no. 10.

10. Dikenshteyn, G.Kh., Retsenziya na knigu "Geologiya SSSR", t. 22, ch. 1 (Turkmrnskaya SSR). [REVIEW OF THE BOOK "GEOLOGY OF SSSR", V. 22, PT. 1 (TURKMENIAN SSR)]: Sov. geol., no. 10.

11. Dmitriyev, G.A., Vnutriformatsinnyye razmyvy v intinskoy uglenosnoy svite. [INTRAFORMATIONAL SCOURS IN THE INTINSK COAL-BEARING FORMATION]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

12. Doskach, A.G. and F.Ya. Levina, K istorii razvitiya prirodnykh landshaftov Turgayskogo progiba. [HISTORY OF

DEVELOPMENT OF NATURAL LANDSCAPES IN THE TURGAY DOWNWARP]: Izvestiya, Akademiya Nauk SSSR, ser. geogr., no. 6.

13. Yentsova, F.I. and L.Kh. Khvaytser, O triasivykh otlozheniyah v Pechorskom basseyne. [TRIASSIC DEPOSITS IN THE PECHORA BASIN]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

14. Zhamoyda, A.I., Novyye dannyye o srednekamennougol'nykh i melovykh otlozheniyakh basseyna r. Avvakumovki (Sikhote-Alin'). [NEW DATA ON MIDDLE CARBONIFEROUS AND CRETACEOUS DEPOSITS IN THE AVVAKUMOVKA RIVER BASIN (SIKHOTE-ALIN')]: Sov. geol., no. 11.

15. Zhukova, Ye.A. and Ye.G. Vinokurova, Ob otlozheneyakh turonskogo yarusa v basseyne Chirchik-Angren. [ON TURONIAN DEPOSITS IN THE CHIRCHIK-ANGREN BASIN]: Doklady, Akad. Nauk UzSSR, no. 10.

16. Zhuravlev, V.S., B.A. Lifanov and A.Ye. Shlezinger, Novyye dannyye o kungurskikh otlozheniyakh zony Khobdinskogo gravitatsionnogo maksimuma v Prikaspiyskoy sineklize. [NEW DATA ON KUNGURIAN DEPOSITS IN THE ZONE OF MAXIMUM GRAVITY IN THE PRICASPIAN SYNECLISE]: Doklady, Akad. Nauk SSSR, t. 129, no. 6.

17. Zhuravleva, Z.A., K stratigrafii drevnikh osadochnykh otlozheniy basseyna srednego techeniya r. Chary. [STRATIGRAPHY OF ANCIENT SEDIMENTS IN THE BASIN OF THE MIDDLE COURSE OF THE CHARA RIVER]: Doklady, Akad. Nauk SSSR, t. 129, no. 6.

18. Ivanova, T.N., Osnovnyye cherty istorii razvitiya magmatizma Tuvy. [PRINCIPAL FEATURES OF THE DEVELOPMENT OF MAGMATIC ACTIVITY IN TUVA]: Sov. geol., no. 11.

19. Isayev, D.I., K morfologii Ketmen'-Tyumbinskay depressii. [ON THE MORPHOLOGY OF THE KETMEN'-TYUBA DEPRESSION]: Izvestiya, Akad. Nauk KirgSSR, ser. yestestv. i tekhn. nauk, t. 1, vyp. 2.

20. Isayev, D.I., Skhema geomorfologicheskogo deleniya territorii Kirgizii. [A SCHEME OF GEOMORPHOLOGICAL SUBDIVISION OF KIRGIZIYA]: Izvestiya, Akad. Nauk KirgSSR, ser. yestestv. i tekhn. nauk, t. 1, vyp. 2.

21. Ismaylov, K.A., O prisutstvii pliotsenovykh otlozheniy v Lerikskom rayone. [ON THE PRESENCE OF PLIOCENE DEPOSITS IN LERIKSKIY REGION]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 10.

22. Kats, N.Ya., Retsenziya na knigu M.I. Neyshtadta "Istoriya lesov i paleogeografiya SSSR v golotsene" (M. AN SSSR, 1957) i o nekotorykh printsipal'nykh voprosakh paleogeografii. [REVIEW OF M.I. NEYSHTADT'S BOOK "HISTORY OF FORESTS AND HOLOCENE PALEOGEOGRAPHY OF THE USSR" (ACAD. SCI. USSR, 1957, MOSCOW) AND REMARKS ON SOME THEORETICAL PROBLEMS OF PALEOGEOGRAPHY]: Botan. zh. Akad. Nauk SSSR, t. 44, no. 9.

23. Kats, N.Ya., Termicheskaya volna pozdnego pleystotsena i razvitiye rastitel'nosti. [THERMAL WAVE OF THE LATE PLEISTOCENE AND THE DEVELOPMENT OF VEGETATION]: Izvestiya Akad. Nauk SSSR, ser. geogr. no. 6.

24. Kireyeva, G.D. and V.P. Stupakov, O rasprostronenii i usloviyakh zaleganiya nizhne-permskikh otlozheniy severovostochnogo Donbassa. [DISTRIBUTION AND CONDITIONS OF DEPOSITION OF THE LOWER PERMIAN DEPOSITS OF NORTHEASTERN DONBAS]: Geol. nefti i gaza, no. 12.

25. Knipper, A.L., O stratigrafii nizhnepaleozoyskikh otlozheniy Yuzhnogo Ulutau (Tsentral'nyy Kazakhstan). [STRATIGRAPHY OF THE LOWER PALEOZOIC DEPOSITS OF SOUTHERN ULUTAU (CENTRAL KAZAKHSTAN)]: Sov. geol. no. 10.

26. Komlev, L.V., V.G. Savonenkov, N.F. Kryukova and G.N. Kuchina, Drevneyshiye porody dokembriya Ukrainy v izluchine Dnepra. [THE OLDEST PRECAMBRIAN ROCKS OF THE UKRAINE IN THE BEND OF THE DNEPR]: Doklady, Akad. Nauk SSSR, t. 129, no. 6.

27. Kornev, V.A., Tektonika rayona ostrova Ogurchinskiy. [TECTONICS OF OGURCHINSKIY ISLAND]: Geol. nefti i gaza, no. 12.

28. Kravchenko, S.M., O vulkanogenno-osadochnoy serii mezozoyskogo magmaticheskogo kompleksa Tsentral'nogo Aldana. [THE TUFF SERIES OF THE MESOZOIC MAGMATIC COMPLEX OF CENTRAL ALDAN]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

29. Kravchenko, G.G., Opyt izucheniya otnositel'noy oriyentirovki razobshchennykh blokov porod, zaklyuchennykh v

intruziyakh. [A STUDY OF RELATIVE ORIENTATION OF SEPARATED BLOCKS INCLUDED IN INTRUSIVES]: Doklady, Akad. Nauk SSSR, t. 129, no. 6.

30. Makarychev, G.I., Novyye dannyye po stratigrafii ordovika Baydzhansayskogo rayona Bol'shogo Karatau (Yuzhnyy Kazakhstan). [NEW DATA ON ORDOVICIAN STRATIGRAPHY OF THE BAYDZHANSAY REGION IN BOL'SHOY KARATAU (SOUTHERN KAZAKHSTAN)]: Izv. vysh. uchebn. zaved., ser. geol. i razvedka, no. 9.

31. Mamatkulov, M.M., K voprosu o kolichestve drevnikh oledneniy basseyna r. Sandalash (R. Chatkal). [ON THE NUMBER OF ANCIENT GLACIATIONS IN THE BASIN OF THE SANDALASH RIVER (CHATKAL RIVER)]: Doklady, Akad. Nauk UzSSR, no. 11.

32. Merkulov, P.M., K geologii drevnikh galechnikov nekotorykh rayonov Yuzhnogo Kitaya. [GEOLOGY OF ANCIENT GRAVEL CONGLOMERATES IN SOME AREAS OF SOUTH CHINA]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

33. Mirzayev, K.M., Drevneye oledneniye severnogo sklona vostochnoy chasti Zaalayskogo khrebta. [ANCIENT GLACIATION OF THE NORTHERN SLOPE IN THE EASTERN PART OF THE ZAALAY RANGE]: Izvestiya, Akad. Nauk, SSSR, ser. geogr., no. 6.

34. Mkrtchyan, O.M., Raschleneniye i korrelyatsiya karbonatnykh tolshch. [SUBDIVISION AND CORRELATION OF CARBONATE BEDS]: Geol. nefti i gaza, no. 12.

35. Myachina, A.I., K voprosu o granitse tretichnykh i chetvertichnykh otlozheniy Amuro-Zeyskoy depressii. [ON THE TERTIARY-QUATERNARY BOUNDARY IN THE AMUR-ZEYA DEPRESSION]: Sov. geol., no. 11.

36. Nestoyanova, O.A., Stratigrafiya devona i silura Magnitogorskogo sinklinoriya. [DEVONIAN AND SILURIAN STRATIGRAPHY OF THE MAGNITOGORS SYNCLINORIUM]: Sov. geol. no. 11.

37. Nikolayeva, T.V., Novyye dannyye po stratigrafii chetvertichnykh otlozheniy Komsomol'skogo rayona. [NEW DATA ON QUATERNARY STRATIGRAPHY OF THE KOMSOMOL'SK REGION]: Sov. geol., no. 11.

38. Orlov, V.I., Ob osobennostyakh rasprostraneniya nekotorykh form rel'yefa v predelakh Zapadno-Sibirskoy nizmennosti. [ON THE PECULIARITIES OF DISTRIBUTION OF RELIEF IN THE WEST SIBERIAN LOWLAND]: Izvestiya, Akad. Nauk SSSR, ser. geogr., no. 6.

39. Osipov, M.A., Malyye intruzii Leninogorskogo rayona Rudnogo Altaya. [MINOR INTRUSIONS OF THE LENINOGORSK REGION IN RUDNYY ALTAY]: Doklady, Akademiya Nauk SSR, t. 129, no. 6.

40. Paprot, Ye. and R.Taykhmyuller, Razvitiye subvaristsiyskogo krayevogo progiba Severo-Zapadnoy Germanii. [DEVELOPMENT OF THE SUB-VARISCAN MARGINAL DOWNWARP IN NORTHWESTERN GERMANY]: Sov. geol. no. 11.

41. Pidoplichko, A.P. and M.A. Konoyko, O vremeni obrazovaniya i osobennostyakh razvitiya ozer i torfyanikov v golotsene na territorii Belorusskoy SSR. [TIME OF FORMATION AND CHARACTERISTICS OF DEVELOPMENT OF LAKES AND PEAT BOGS IN BELORUSSIAN SSR]: Doklady, BSSR, t. 3, no. 11.

42. Plaksenko, N.A., K voprosu o stratigraficheskom pereryve mezhdu zhelezistymi kvartsitami i kroyushchimi ikh porodami dokembriya Kurskoy magnitnoy anomalii. [ON THE STRATIGRAPHIC BREAK BETWEEN FERRUGINOUS QUARTZITES AND THE OVERLYING PRECAMBRIAN ROCKS OF THE KURSK MAGNETIC ANOMALY]: Byull. Nauchn.-tekhn. obshchestva chern. matallurgii komb. "KMAruda" i fil. IGD Akad. Nauk SSSR, no. 1(8).

43. Polevaya, N.I., Vos'maya sessiya komissii po opredeleniyu absolyutnogo vozrasta geologicheskoy formatsii [EIGHTH SESSION OF THE COMMITTEE FOR DETERMINATION OF ABSOLUTE AGES OF GEOLOGICAL FORMATIONS]: Sov. geol., no. 11.

44. Preobrazhenskaya, V.N., Istoriya izucheniya yurskikh otlozheniy territorii KMA. [HISTORY OF INVESTIGATION OF JURASSIC DEPOSITS IN THE KMA TERRITORY]: Byul. Nauchn.-tekhn. obshchestva chern. metallurgii komb. "KMAruda" i fil. IGD Akad. Nauk SSSR, no. 1(8).

45. Romanov, I.S., Chetvertichnyy vulkanicheskiy pepel basseyna r. Merly. [QUATERNARY VOLCANIC ASH OF THE MERLA RIVER BASIN]: Sov. geol., no. 10.

46. Rubinshteyn, M.M., K peresmotru absolyutnoy geokhronologicheskoy shkaly. [ON THE REVISION OF THE ABSOLUTE GEOCHRONOLOGICAL SCALE]: Doklady, Akad. Nauk SSSR t. 129, no. 5.

47. Saltykova, N.P. and A.Ye. Shlezinger, Morskiye al'bskiye otlozheniya v basseynakh rek Uila, Bol'shoy Khobdy i Ileka (Zapadnyy Kazakhstan). [MARINE ALBIAN DEPOSITS IN THE BASINS OF THE UIL, BOL'SHAYA KHOBDA AND ILEK RIVERS (WESTERN KAZAKHSTAN)]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

48. Sarkisyan, O.A., Skhema stratigraficheskogo raschleneniya paleogenovykh obrazovaniy Sevano-Shirakskogo sinklinoriya. [AN OUTLINE OF STRATIGRAPHIC SUBDIVISION OF THE PELEOGENE DEPOSITS OF THE SEVAN-SHIRAK SYNCLINORIUM]: Doklady, Akad. Nauk ArmSSR, t. 29, no. 3.

49. Skvaletskiy, Ye.N., Osnovnyye cherty geomorfologii vostochnoy chasti At-Bashinskoy vpadiny. [MAIN FEATURES OF GEOMORPHOLOGY OF THE EASTEARN PART OF THE AT-BASHINSK BASIN]: Izvestiya, Akad. Nauk KirgSSR, ser. yestestv. i tekhn. nauk, t. 1, vyp. 2.

50. Smirnov, G.A. and G.G. Fedorova, Rol' mekhanicheskogo pereraspredeleniya chastits v sadkakh pri diageneze v obrazovanii sloistosti. [ROLE OF MECHANICAL REDISTRIBUTION OF PARTICLES IN SEDIMENTS DURING DIAGENESIS IN THE FORMATION OF LAMINATION]: Doklady, Akademiya Nauk SSSR, t. 129, no. 4.

51. Sokolova, N.N., G.I. Teodorovich and R.O. Khachatryan, Raschleneniye turneysko-vizeyskoy terrigennoy tolshchi yuga Kamsko-Kinel'skoy vpadiny. [SUBDIVISION OF THE CONTINENTAL TOURNAISIAN-VISEAN SEQUENCE IN THE SOUTH OF THE KAMA-KINEL' DEPRESSION]: Sov. geol., no. 10.

52. Solov'yev, V.F., L.S. Kulakova and G.V. Agapova, Novyye dannyye o tektonicheskoy strukture dna Yuzhnogo Kaspiya. [NEW DATA ON THE STRUCTURE OF SOUTH CASPIAN BOTTOM]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

53. Solov'yev, S.P., Osobennosti razvitiya vo vremeni metamorficheskikh gornykh porod na territirii SSSR. [CHARACTERISTICS OF DEVELOPMENT OF METAMORPHIC ROCKS OF THE USSR IN TIME]: Zap. Vses. mineralog. obshchestva, ch. 88, vyp. 6.

54. Sultanova, Z.Z., Nekotoryye suzhdeniya iz issledovaniy zapisey izverzhenykh vulkanov. [SOME CONCLUSIONS FROM THE RECORDS OF VOLCANIC ERUPTIONS]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 5.

55. Tairov, Ch.A., Raschleneniye melovykh otlozheniy severo-vostochnogo Azerbaydzhana po mikrofaune. [SUBDIVISION OF CRETACEOUS DEPOSITS OF NORTHEASTEARN AZERBAYDZHAN ON THE BASIS OF MICROFAUNAS]: Geol. nefti i gaza, no. 12.

56. Tarkhov, A.G., Retsenziya na knigu D.I. D'yakonova "Geotermiya v neftyanoy geologii". [GEOTHERMY IN PETROLEUM GEOLOGY]: M. Gostoptekhizdat, 1958, Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 9.

57. Udintsev, G.B., Rezul'taty seysmoakusticheskikh issledovaniy stroyeniya dna Tikhogo okeana k yugo-vostoku ot o. Khokkaydo. [RESULTS OF SEISMIC-ACOUSTIC INVESTIGATIONS OF THE STRUCTURE OF THE PACIFIC OCEAN BOTTOM TO THE SOUTHEAST OF HOKKAIDO]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

58. Umarov, A., K kharakteristike formirovaniya lokal'nykh skladok Sarytash-Dzharkakskoy plakantiklinali. [ON THE FORMATION OF LOCAL FOLDS IN THE SARYTASH-DZHARKAK PLACANTICLINE]: Doklady, UzSSR, no. 11.

59. Khalfin, L.L., Osadochnyye geologicheskiye formatsii v stratigraficheskom aspekte. [THE STRATIGRAPHIC ASPECT OF SEDIMENTARY GEOLOGICAL FORMATIONS]: Sov. geol., no. 10.

60. Chernyshev, N.I., Verkhnepermskiye konkretsionnyye obrazovaniya Prikam'ya. [UPPER PERMIAN CONCRETIONARY STRUCTURES IN THE KAMA REGION]: Sov. geol., no. 10.

61. Sheydayeva-Kuliyeva, Kh.M., Stratigrafiya ponticheskikh otlozheniy Marazinskogo (S. Syundi) i Shemakhinskogo (Khynyslinskoye ushcheliye) rayonov Azerbaydzhana. [STRATIGRAPHY OF PONTIC DEPOSITS IN THE MARAZIN (VILLAGE OF SYUNDI) AND SHEMAKHIN (KHYNYSLIN CANYON) REGIONS OF AZERBAYDZHAN]: Doklady, Akad. Nauk, AzerbSSR, t. 15, no. 10

62. Shikhalibeyli, E.Sh. and G.P. Kornev, Tektonicheskoye stroyeniye vostochnoy chasti Malogo Kavkaza. [GEOLOGIC STRUCTURE OF THE EASTERN PART OF THE LESSER CAUCASUS]: Sov. geol., no. 11.

63. Yakovlev, G.F., Osnovnyye tipy rayonov Rudnogo Altaya. [PRINCIPAL TYPES OF REGIONS IN RUDNYY ALTAY]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

PALEONTOLOGY

64. Alekseyeva, L.I., Verblyud iz ponticheskikh otlozheniy Kryma. [CAMEL FROM PONTIC DEPOSITS OF CRIMEA]: Paleontol. zh., no. 3.

65. Alekseyeva, L.I., Mastodont serridentinus gobiensis iz Beger-Nura (Mongoliya). [MASTODONT SERRIDENTINUS GOBIENSIS FROM BEGER-NUR (MONGOLIA)]: Paleontol. zh., no. 3.

66. Atabekyan, A.A., O sredneal'bskom ammonite okrestnostey sel. Verin Agdan (Armyanskaya SSR). [A MIDDLE ALBIAN AMMONITE FROM THE VICINITY OF THE VILLAGE OF VERIN AGDAN (ARMENIAN SSR)]: Doklady, Akad. Nauk ArmSSR, t. 29, no. 3.

67. Barskov, I.S., Novyye siluriyskiye nautiloidei iz Yuzhnoy Fergany. [NEW SILURIAN NAUTILOIDS FROM SOUTHERN FERGANA]: Paleontol. zh. no. 3.

68. Bekker-Migdisova, Ye.E., Novyy rod Borisrohdendorfia (Homoptera) iz kuznetskoy svity Kuznetskogo basseyna. [NEW GENUS BORISROHDENDORFIA (HOMOPTERA) FROM KUZNETSK FORMATION OF THE KUZNETSK BASIN]: Paleontol. zh., no. 3.

69. Bogoslovskiy, B.I., Novyye predstaviteli ammonoidey iz srednedevonskikh otlozheniy Polyarnogo Urala. [NEW AMMONOIDS FROM THE MIDDLE DEVONIAN DEPOSITS OF THE POLAR URALS]: Paleontol. zh. no. 3.

70. Vakrameyev, V.A. and R.A. Vasina, Nizheyurskaya i aalenskaya flory Severnogo Kavkaza. [LOWER JURASSIC AND AALENIAN FLORAS OF NORTHERN CAUCASUS]: Paleontol. zh. no. 3.

71. Vladimirovich, V.P., K izucheniyu pozdnetriasovoy - ranneyurskoy flory Vostochnogo Urala. [ON THE LATE TRIASSIC-EARLY JURASSIC FLORA OF EASTERN URALS]: Botan. zh. Akad. Nauk SSSR, t. 44, no. 4.

72. Vologdin, A.G., Tri vida arkheotsiat iz sibiretsiatovoy zony nizhnego kembriya Baykal'skogo nagor'ya. [THREE SPECIES OF ARCHAEOCYATHIDS FROM THE LOWER CAMBRIAN SIBIRECYATHID ZONE OF THE BAYKAL UPLAND]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

73. Vorob'yeva-Blokhina, E.I., Novyy rod kistepernykh ryb Platycephalichthys iz verkhnego devona r. Lovat'. [NEW GENUS OF CROSSOPTERYGIAN FISH, PLATYCEPHALICHTHYS FROM THE UPPER DEVONIAN OF THE LOVAT' RIVER]: Paleontol. zh., no. 3.

74. Vyalov, O.S. and V.B. Timofeyev., Pervaya nakhodka drevnikh spor v Antarktide. [FIRST FIND OF ANCIENT SPORES IN ANTARCTICA]: Dopovidi, Akad. Nauk URSR, no. 10.

75. Gregush, P., Okremenelyy stvol dereva iz nizhnego eotsena basseyna Volgi. [PETRIFIED TREE TRUNK FROM THE LOWER EOCENE OF THE VOLGA BASIN]: Paleontol. zh., no. 3.

76. Delle, G.V., Ginkgovyye (Gingkoales) iz yurskikh otlozheniy Tkvarchel'skogo uglenosnogo basseyna v Zakavkaz'ye [GINGKOES FROM THE JURASSIC DEPOSITS OF THE TKVARCHEL' COAL BASIN IN TRANSCAUCASIA]: Botan. zh. Akad. Nauk SSSR, t. 44, no. 1.

77. Zhuze, A.P., Osnovnyye etapy razvitiya flory morskikh diatomovykh vodorosley (Diatomeae) na Dal'nem Vostoke v tretichnom i chetvertichnom periodakh. [MAIN STAGES OF DEVELOPMENT OF MARINE DIATOM FLORA IN THE FAR EAST DURING TERTIARY AND QUATERNARY PERIODS]: Boton. zh. Akad. Nauk SSSR, t. 44, no. 1.

78. Koltun, V.M., Spikul'nyy analiz kak mikropaleontologicheskiy metod issledovaniya. [SPICULE ANALYSIS AS A MICROPALEONTOLOGICAL METHOD OF INVESTIGATION]: Paleontol. zh., no. 3.

79. Korniyets, N.L., K voprosu o prichinakh vymiraniya mamonta na Ukraine. [ON THE CAUSES OF EXTINCTION OF MAMMOTH IN THE UKRAINE]: Dopovidi, Akad. Nauk URSR, no. 10.

80. Krasilova, I.N., Novoye semeystvo Leiopectinidae iz verkhnesiluriyskikh i nizhnedevonskikh otlozheniy Severo-Vostochnogo Pribalkhash'ya. [NEW FAMILY OF LEIOPECTINIDAE FROM THE UPPER SILURIAN AND LOWER DEVONIAN DEPOSITS OF THE NORTHEASTERN BALKHASH REGION]: Paleontol. zh., no. 3.

81. Kuznetsova, T.A., K kharakteristike flory akchagyl'skikh otlozheniy Nizhney Kamy i Kuybyshevsko-Saratovskogo Zavolzh'ya. [A DESCRIPTION OF FLORA FROM THE ARCHAGYL' DEPOSITS OF THE LOWER KAMA RIVER AND THE KUYBYSHEV-SARATOV REGION OF THE VOLGA]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

82. Martinson, G.G., O novom rode yurskikh

plastinchatozhabernykh Pseudocardinia. [A NEW GENUS OF JURASSIC PELECYPODA, PSEUDOCARDINIA]: Paleontol. zh., no. 3.

83. Obruchev, D.V., Ob ikhtiodorulite Ctenacanthus venator Chabakov, 1928. [CONCERNING ICHTHYODORULITE: CTENACANTHUS VENATOR CHABAKOV, 1928]: Paleontol. zh., no. 3.

84. Obruchev, O.P., Dva vida Plourdosteus (Arthrodira) iz verkhnedevonskikh otlozheniy SSSR. [TWO SPECIES OF PLOURDOSTEUS (ARTHRODIRA) FROM UPPER DEVONIAN OF THE USSR]: Paleontol. zh., no. 3.

85. Rodendorf, B.B., Voprosy paleozoologicheskoy sistematiki. [PROBLEMS OF PALEOZOOLOGICAL SYSTEMATICS]: Paleont. zh., no. 3.

86. Rozman, Kh.S., Enantiosphen Whidborne iz zhivetskikh otlozheniy Yuzhnykh Mugodzhar. [ENANTIOSPHEN WHIDBORNE FROM THE ZHIVETIAN OF THE SOUTHERN MUGODZHAR MOUNTAINS]: Paleont. zh., no. 3.

87. Saidova, Kh.M., Raspredeleniye foraminifer v donnykh otlozheniyakh i paleogeografiya severo-zapadnoy chasti Tikhogo okeana. [DISTRIBUTION OF FORAMINIFERA IN THE BOTTOM SEDIMENTS AND PALEOGEOGRAPHY OF THE NORTHWESTERN PACIFIC]: Doklady, Akad. Nauk SSSR, t. 129, no. 6.

88. Samylina, V.A., Novyye nakhodki pokrytosemyannykh rasteniy v nizhnemelovykh otlozheniyakh Kolymy. [NEW FINDS OF ANGIOSPEMS IN THE LOWER CRETACEOUS DEPOSITS OF KOLYMA]: Botan. zh. Akademiya Nauk SSSR, t. 44, no. 4.

89. Sveshnikova, I.N. and L.Yu. Budantsev, Tretichnaya flora Kaliningradskogo poluostrova. [TERTIARY FLORA OF KALINGRAD PENINSULA]: Botan. zh. Akad. Nauk SSSR, t. 44, no. 2.

90. Svistun, V.I., Iskopayemyye mlekopitayushchiye allyuvial'nykh otlozheniy rayona Dneprodzerzhinskoy GES. [FOSSIL MAMMALS FROM THE ALLUVIUM IN THE REGION OF DNEPRODZERZHINS HYDROELECTRIC STATION]: Dopovidi, Akad. Nauk USSR, no. 10.

91. Sokolov, B.S. and N.V. Mironova, O novom rode ordovikskikh korallov Zapadnoy Sibiri i Severnogo Kazakhstana. [A NEW GENUS OF ORDOVICIAN CORALS FROM WESTERN SIBERIA AND NORTHERN KAZAKHSTAN]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

92. Stepanov, D.L., Politipicheskaya kontseptsiya vida v paleontologii. [THE POLYTYPE CONCEPT OF SPECIES IN PALEONTOLOGY]: Paleont. zh. no. 3.

93. Suvorova, N.P., Novyye trilobity nadsemeystv Corynexochoidea i Redlichioidea lenskogo yarusa nizhnego kembriya Yakutii. [NEW TRILOBITES OF SUPERFAMILIES CORYNEXOCHOIDEA AND REDLICHIOIDEA FROM THE LOWER CAMBRIAN LENA STAGE OF YAKUTIYA]: Paleont. zh. no. 3.

94. Tatarinov, L.P., Osobennosti zvukoprovodyashchego apparata iskopayemykh i sovremennykh cherepakh. [PECULIARITIES OF THE HEARING ORGANS OF MODERN AND FOSSIL TURTLES]: Paleont. zh. no. 3.

95. Teslenko, Yu.V., Materialy k izucheniyu miotsenovoy flory Severnogo Priazov'ya. [MATERIALS ON THE MIOCENE FLORA OF NORTHERN PRIAZOV'YE]: Botan. zh. Akad. Nauk SSSR, t. 44, no. 1.

96. Chzhan-Chzhao-Chen, Plicatomurus gen. nov. (Favositidae) iz verkhnesiluriyskikh otlozheniy tsentral'nogo Kazakhstana. [PLICATOMURUS GEN. NOV. FROM THE UPPER SILURIAN DEPOSITS OF CENTRAL KAZAKHSTAN]: Paleontol. zh., no. 3.

97. Yakovlev, V.N., Ryby iz miotsenovykh otlozheniy Kirgizii. [FISH FROM THE MIOCENE OF KIRGIZIYA]: Paleontol. zh., no. 3.

98. Yanovskaya, N.M., Vsesoyuznoye paleontologicheskoye soveshchaniye. [ALL-UNION PALEONTOLOGICAL CONFERENCE]: Izvestiya, Akad. Nauk SSSR, ser. biol. no. 6.

99. Yataykin, L.M., Novyye dannyye ob iskopayemoy flore iz izvestkovykh tufov Chistopolya. [NEW DATA ON FOSSIL FLORA FROM THE CALCAREOUS TUFA OF CHISTOPOL'YE]: Botan. zh. Akad. Nauk SSSR, t. 44, no. 9.

100. Yakhimovich, N.N., Ob ostatkakh krupnoy antilopy iz verkhnepliotsenovykh otlozheniy Yuzhnogo Urala. [REMAINS OF A LARGE ANTELOPE FROM THE UPPER PLIOCENE OF THE SOUTHERN URALS]: Paleont. zh., no. 3.

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101. Abdullayev, R.N., Verkhnemelovyye al'bitofiry i kvartsevyye al'bitofiry severo-vostochnoy chasti Malogo Kavkaza. [UPPER CRETACEOUS ALBITOPHYRES AND QUARTZ ALBITOPHYRES OF THE

LESSER CAUCASUS]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 10.

102. Abramovich, Ye.L., Nekotoryye rezul'taty mineralogo-petrograficheskikh issledovaniy karbonatnykh otlozheniy D_{2+3} Pritashkentskogo rayona. [SOME RESULTS OF MINERALOGICAL AND PETROGRAPHIC INVESTIGATIONS OF THE D_{2+3} KARBONATE DEPOSITS OF THE TASHKENT REGION]: Doklady, Akad. Nauk UzSSR, no. 10.

103. Akademik, Ye.S., Fedorov. Yubiley. [ACADEMICIAN YE.S. FEDOROV. ANNIVERSARY]: Izvestiya, Akad. Nauk KazSSR, ser. geol., vyp. 2 (35).

104. Bazhenov, A.I., O transvaalite iz mestorozhdeniya Yugo-Vostochnogo Altaya. [TRANSVAALITE FROM A DEPOSIT IN SOUTHEASTERN ALTAY]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

105. Belevtsev, Ya.N., Yu.M. yepatko and A.I. Strygin, Glubinnyye zony okisleniya v porodakh Krivorozhskogo basseyna. [DEEP OXIDIZED ZONES IN THE ROCKS OF THE KRIVOY ROG BASIN]: Sov. geol., no. 11.

106. Belov, N.V., Razvernutyye formuly berilla. [DEVELOPED FORMULAS OF BERYL]: Geokhimiya, no. 8.

107. Beus, A.A., O zavisimosti mezhdu soderzhaniyem litiya, natriya i tseziya v shchelochnykh berillakh. [ON THE RELATION BETWEEN THE CONTENT OF LITHIUM, SODIUM AND CESIUM IN ALKALI BERYLS]: Geokhimiya, no. 8.

108. Bogolepov, V.G., Ob aktivnom i passivnom povedenii elementov pri metasomatoze. [ACTIVE AND PASSIVE BEHAVIOR OF THE ELEMENTS DURING METASOMATISM]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

109. Bondareva, A.M., D.L. Rogachev and A.S. Sakharov, Litiysoderzhashchiy shchelochnoy amfibol iz kontaktnoy zony Lovozerskogo massiva. [LITHIUM-BEARING ALKALIC AMPHIBOLE FROM THE CONTACT ZONE OF THE LOVOZERO MASSIF]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

110. Vardanyants, L.A. and A.Ya. Dubinskiy, Kristallicheskiye porody Azovskoy anteklizy. [CRYSTALLINE ROCKS OF THE AZOV DOME]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

111. Vinogradov, A.P. et al., Opredeleniye absolyutnogo vozrasta po C^{14}. Soobshcheniye 2. [DETERMINATION OF ABSOLUTE AGE BY C^{14}. REPORT 2]: Geokhimiya, no. 8.

112. Dmitriyev, Yu.I., Trappovyy magmatizm i gidrotermal'naya mineralizatsiya r. Chony. [BASALTIC VOLCANISM AND HYDROTHERMAL MINERALIZATION ON THE CHONA RIVER]: Sov. geol., no. 10.

113. Dobretsov, N.L., O vzaimosvyazi mezhdu glavnymi ionami rombicheskikh piroksenov i ikh vliyaniye na opticheskiye svoystva mineralov. [ON THE MUTUAL RELATIONSHIP AMONG THE MAIN IONS IN ORTHOPYROXENES AND ITS EFFECT ON THE OPTICAL PROPERTIES OF THE MINERALS]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

114. Dontsova, Ye.I., Metod opredeleniya sootnosheniy izotopov kisloroda v gornykh porodakh i mineralakh. [METHOD OF DETERMINATION OF OXYGEN ISOTOPE RATIOS IN ROCKS AND MINERALS]: Geokhimiya, no. 8.

115. Dudkin, O.B., O bariyevom lamprofillite. [BARIUM LAMPROPHYLLITE]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

116. Yefimov, A.F. and Z.T. Katayeva, Pervaya nakhodka leykosfenita v SSSR. [FIRST FIND OF LEUCOSPHENITE IN THE USSR]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

117. Ilyukhin, V.V. and Ye.I. Semenov, Novyye dannyye ob ussingite. [NEW DATA ON USSINGITE]: Doklady Akad. Nauk SSSR, t. 129, no. 6.

118. Kamentsev, I.Ye., K voprosu o vliyanii aktivnoy podlozhki na izmeneniye oblika kristallov apatita. [ON THE EFFECT OF ACTIVE SUBSTRATUM ON THE CRYSTAL HABIT OF APATITE]: Zap. Vses. min. o-va, t. 88, vyp. 6.

119. Kerimov, G.I., K klassifikatsii osnovnykh i ul'traosnovnykh porod. [ON CLASSIFICATION OF BASIC AND ULTRABASIC ROCKS]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 10

120. Klevtsov, P.V. and G.G. Lemmleyn, Opredeleniye minimal'nogo davleniya obrazovaniya kvartza na primere kristallov s Pamira. [DETERMINATION OF THE MINIMUM PRESSURE OF FORMATION OF QUARTZ CRYSTALS USING CRYSTALS FROM THE PAMIRS AS AN EXAMPLE]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

121. Komarova, G.N. and L.Ye. Novorossova,

O povedenii olova i indiya v kollomorfnykh agregatakh kassiterita iz Dzhalindinskogo mestorozhdeniya na Malom Khingane. [ON THE BEHAVIOR OF TIN AND INDIUM IN COLLOFORM CASSITERITE FROM THE DZHALINDIN DEPOSIT OF MALYY KHINGAN]: Geokhimiya, no. 8.

122. Komkov, A.I., O rentgenovskoy diagnostike mineralov gruppy fergusonita. [ON X-RAY IDENTIFICATION OF THE FERGUSONITE GROUP MINERALS]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

123. Konovalov, G.S., Vynos mikroelementov glavneyshimi rekami SSSR. [TRANSPORT OF TRACE ELEMENTS BY THE PRINCIPAL RIVERS OF THE USSR]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

124. Kossovskaya, A.G., Osnovnyye parageneticheskiye mineral'nyye assotsiatsii v mezozoyskikh otlozheniyakh yugo-vostoka Vilyuyskoy vpadiny i zapadnogo Verkhoyan'ya. [PRINCIPAL MINERAL PARAGENESES IN THE MESOZOIC DEPOSITS OF THE SOUTHEAST VILYUY BASIN AND WESTERN VERKHOYANSK REGION]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

125. Kossovskaya, A.G., Faktory opredelyayushchiye formirovaniye mineral'nogo sostava glin v usloviyakh platformi i geosinklinali. [FACTORS DETERMINING THE MINERALOGICAL COMPOSITION OF CLAYS IN PLATFORM AND GEOSYNCLINAL ENVIRONMENTS]: Doklady, Akad. Nauk SSSR, t. 129, no. 6.

126. Lebedev, V.I., O prichinakh okisleniya urana v uraninitakh. [THE CAUSES OF OXIDATION OF URANIUM IN URANINITES]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

127. Leyye, Yu.A., Novyye dannyye o fatsiyakh, vozraste i vzaimosvyazi kvartsevykh porfirov Kafanskogo rudnogo polya. [NEW DATA ON FACIES, AGE AND RELATIONSHIP OF THE RHYOLITES IN THE KAFANA MINERALIZED AREA]: Doklady, Akad. Nauk ArmSSR, t. 29, no. 3.

128. Lobanova, V.V. and E.Kh. Khurshudyan, Issledovaniye kristallov sul'foborita Inderskogo mestorozhdeniya. [INVESTIGATION OF SULFOBORITE CRYSTALS OF THE INDER DEPOSIT]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

129. Mineyev, D.A. and N.I. Stupnikova, O prirode radioaktivnosti oritov i sootnoshenii v nikh urana, toriya i redkikh zemel'. [ON THE NATURE OF RADIOACTIVITY IN ALLANITES AND ON RELATIONSHIP BETWEEN URANIUM, THORIUM AND THE RARE EARTHS IN THEM]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

130. Miroshnikov, L.D. and O.S. Shcheglova, O kontsentratsii vodnorastvorimykh sul'fatov na poluostrove Chelyuskina. [ON THE CONCENTRATION OF WATER-SOLUBLE SULFATES ON CHELYUSKIN'S PENINSULA]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

131. Mirskaya, D.D., O genezise amfibolitov svity Keyv. [THE GENESIS OF AMPHIBOLITES OF THE KEYV FORMATION]: Izv. Karel'sk i Kol'sk. fil. Akad. Nauk SSSR, no. 3.

132. Moiseyeva, M.I., O nakhodke sampleita v rudakh mednogo mestorozhdeniya Kal'makyr v Almalykskom rayone. [ON THE DISCOVERY OF SAMPLEITE IN THE ORES OF THE KAL'MAKYR DEPOSIT IN THE ALMALYK REGION]: Doklady, Akad. Nauk UzSSR, no. 10.

133. Nazarenko, M.F., O vliyanii vozmozhnoy struktury shchelochnosilikatnogo rasplava na modifikatsionnyye izmeneniya kvartsa. [THE EFFECT OF POSSIBLE STRUCTURE OF THE ALKALINE SILICATE MELT ON THE MODIFICATIONS OF QUARTZ]: Vestn. Akad. Nauk KazSSR, no. 10.

134. Ovchinnikov, L.N. et al., K voprosu o sokhrannosti argona v slyudakh. [THE QUESTION OF RETENTION OF ARGON BY MICAS]: Geokhimiya, no. 8.

135. Pirozhnikov, L.P., Slyudyanyye alevrity o. Viner-Neyshtadt i slyudyanyye peschaniki o. Champ (arkhipelag Zemlya Frantsa Iosifa). [MICACEOUS SILTSTONES OF WIENER-NEYSTADT ISLAND AND MICACEOUS SANDSTONES OF CHAMP ISLAND (FRANZ-JOSEPH ARCHIPELAGO]: Doklady, Akad. Nauk SSSR, t. 129, no. 6.

136. Pobedimskaya, Ye.A. and N.V. Belov, Kristallicheskaya struktura epididimita $NaBeSi_3O_7(OH)$. Novyy tip beskonechnykh kremnekislorodnykh tsepochek (lent). [CRYSTAL STRUCTURE OF EPIDIDYMITE, $NaBeSi_3O_7(OH)$. A NEW TYPE OF SILICON-OXYGEN CHAINS (BANDS)]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

137. Proskurko, A.I., Epi - i psevdoleytsity shchelochnykh effuziy Pamira. [EPI - AND PSEUDOLEUCITES OF THE PAMIR EXTRUSIVES]: Doklady, Akad. Nauk SSSR, t. 129, no. 6.

138. Razumovskiy, N.K., Tsilindricheskiye preparaty dlya izucheniya pokazateley prelomleniya mineralov immersionnym metodom. [CYLINDRICAL PREPARATIONS

FOR THE STUDY OF REFRACTIVE INDICES BY THE IMMERSION METHOD]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

139. Satpayeva, T.A., S.K. Kalinin and E.Ye. Fayn, Spektrograficheskoye izucheniye mednykh rud Dzhezkazgana na redkiye i rasseyannye elementy. [SPECTROGRAPHIC INVESTIGATION OF THE DZHEZKAZGAN COPPER ORES FOR RARE AND DISPERSED ELEMENTS]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 2(35).

140. Seidov, A.G., O mineralogicheskom sostave glin maykopskoy svity Azebaydzhana. [THE MINERALOGICAL COMPOSITION OF THE MAYKOP FORMATION OF AZERBAYDZHAN]: Doklady, Akad. Nauk AzerbSSR, t. 15, no. 10.

141. Sobolev, N.D., K Petrokhimii ul'traosnovnykh gornykh porod. [PETROCHEMISTRY OF ULTRABASIC ROCKS]: Geokhimiya, no. 8.

142. Sobolev, R.N., O kaliyevykh polevykh shpatakh devonskikh granitoidov Tsentral'nogo Kazakhstana. [POTASSIUM FELDSPARS OF THE GRANITOIDS OF CENTRAL KAZAKHSTAN]: Sov. geol., no. 11.

143. Starik, I.Ye. et al., Kontsentratsiya izotopov toriya v vodakh Chernogo morya. [CONCENTRATION OF THORIUM ISOTOPES IN THE BLACK SEA WATERS]: Doklady, Akad. Nauk SSSR, t. 129, no. 4.

144. Starik, I.Ye., V.V. Kurbatov and L.A. Litvina, O vliyanii nagreva na strukturu slyud i mikroklina i o sokhrannosti v nikh argona. [THE EFFECT OF HEATING ON THE STRUCTURE OF MICAS AND MICROCLINE AND THE RETENTION OF ARGON]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

145. Starik, I.Ye., et al., Raspredeleniye radioelementov v osadkakh Chernogo morya. [DISTRIBUTION OF RADIOACTIVE ELEMENTS IN THE BLACK SEA SEDIMENTS]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

146. Tazhibayeva, P.T., Osobennosti granulometricheskogo sostava porod verkhnepaleozoyskogo osadochnogo kompleksa Dzhezkazgan-Ulutauskogo rayona. [CHARACTERISTICS OF THE GRANUMETRIC COMPOSITION OF THE DZHEZKAZGAN-ULUTAU SEDIMENTARY COMPLEX]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 2 (35).

147. Teodorovich, G.I., V.S. Melamedova and I.A. Pisarenko, K metodike diagnosticheskogo okrashivaniya zhelezistomagnezialnykh karbonatov. [ON THE METHOD OF DIAGNOSTIC STAINING OF IRON-MAGNESIUM CARBONATES]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 9.

148. Uklonskiy, A.S., Izobary, izotony ustoychivykh izotopov i ikh paraelementy. [ISOBARS, ISOTONES OD STABLE ISOTOPES AND THEIR PARAELEMENTS]: Doklady, Akad. Nauk UzSSR, no. 11.

149. Usenko, I.S., Nekotoryye dannyye parageneticheskogo analiza mineralov ul'traosnovnykh porod zapadnogo Priazov'ya. [SOME RESULTS OF PARAGENETIC ANALYSIS OF MINERALS FROM ULTRABASIC ROCKS OF WESTERN AZOV REGION]: Dopovidi, Akad. Nauk URSR, no. 10.

50. Fedorchuk, V.P., O genezise glinistykh mineralov v rtutno-sur'myanykh mestorozhdeniyakh Yuzhnoy Fergany. [THE ORIGIN OF CLAY MINERALS IN THE MERCURY-ANTIMONY DEPOSITS OF SOUTHERN FERGANA]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

151. Khlestov, V.V., Nomogramma dyla opredeleniya ugla opticheskikh osey metodom A.N. Zavaritskogo. [NOMOGRAMFOR DETERMINATION OF AXIAL ANGLE BY A.N. ZAVARITSKIY'S METHOD]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

152. Chernopyatov, S.F. and E.P. Sal'dau, Vismutin v rudakh Sadonskogo mestorozhdeniya. [BISMUTHINITE IN THE ORES OF THE SADONSK DEPOSIT]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

153. Chistyakov, V.K., Rogovyye obmanki iz skarnov Uyzokskogo zhelezorudnogo rayona v Gornoy Shorii. [HORNBLENDES FROM THE SKARNS OF THE UYZOK IRON REGION OF GORNAYA SHORIYA]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 9.

154. Shvetsov, M.S., Pervoye soveshchaniye o postanovke prepodavaniya petrografii osadochnykh porod. [FIRST CONFERENCE ON TEACHING PETROGRAPHY OF SEDIMENTARY ROCKS]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 9.

155. Shcherbina, V.V., Faktory, opredelyayushchiye geokhimicheskoye raspredeleniye skandiya. [FACTORS DETERMINING GEOCHEMICAL DISTRIBUTION OF SCANDIUM]: Geokhimiya, no. 8.

156. Shcherbina, V.V., Fedorovskaya sessiya po kristallografii. [FEDOROV CRYSTALLOGRAPHIC SESSION]: Geokhimiya, no. 8.

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157. Avrov, P. Ya. and S. Ye. Chakabayev, Geologicheskiye predposylki razvitiya neftyanoy i gazovoy promyshlennosti Kazakhstana na 1959-1965 gg. [GEOLOGICAL BASIS FOR THE DEVELOPMENT OF OIL AND GAS INDUSTRY IN KAZAKHSTAN IN 1959-1965]: Izv. Akad. Nauk KazSSR, ser. geol., vyp. 2 (35).

158. Bezhayev, M.M. and V.A. Knyazev, Novyye dannyye o proiskhozhdenii brekchirovannykh ugley Volchanskogo burougol'nogo mestorozhdeniya na Severnom Urale. [NEW DATA ON THE ORIGIN OF THE VOLCHANSK LIGNITE DEPOSIT IN THE NORTHERN URALS]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

159. Borisov, P.A., Keyvskiye resursy slyudyanoy cheshuyki. [THE KEYV RESERVES OF FINE-FLAKE MICA]: Izv. Karel'sk. i Kol'sk. fil. Akad. Nauk SSSR, no. 3.

160. Buryakovskiy, L.A., Litologicheskiye osobennosti mestorozhdeniya Neftyanyye Kamni po dannym promyslovoy geofiziki. [LITHOLOGICAL PECULIARITIES OF THE NEFTYANYYE KAMNI DEPOSIT ACCORDING TO THE GEOPHYSICAL DATA]: Izv. vyssh. uchebn. zaved., ser. neft' i gaz, no. 12.

161. Vasil'kova, N.N., A.G. Teremetskaya and V.T. Shatskaya, Olovorudnyye mestorozhdeniya svyazannyye s subvulkanicheskimi telami. [TIN DEPOSITS RELATED TO SUBVOLCANIC BODIES]: Sov. geol., no. 10.

162. Galin, V.L., Strukturnyye osobennosti i persepktivy neftegazonosnosti Ekendil'-Adzhinourskoy ploshchadi v Yuzhnom Dagestane. [STRUCTURAL PECULIARITIES AND GAS AND OIL PROSPECTS OF THE EKENDIL'-ADZHINOUR AREA IN SOUTHERN DAGESTAN]: Izv. vyssh. uchebn. zaved., ser. neft' i gaz, no. 12.

163. Delchev, A.G. and S.N. Tonev, Poleznyye iskopayemyye Bolgarii. [MINERAL RESOURCES OF BULGARIA]: Razv. i okhrana nedr., no. 11.

164. Isayenko, M.P., Yavleniya karbonatizatsii v medno-molibdenovykh i molibdenovykh mestorozhdeniyakh Zakavkaz'ya. [CARBONATIZATION IN COPPER-MOLYBDENUM AND MOLYBDENUM ORE DEPOSITS OF TRANSCAUCASIA]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 9.

165. K shestidesyatiletiyu K.I. Satpayeva. [ON K.I. SATPAYEV'S SIXTIETH BIRTHDAY]: Izvestiya, Akad. Nauk KazSSR, ser. geol., vyp. 2 (35).

166. Kazanli, D.N., Razvitiye geologorazvedochnogo izucheniya Dzhezgazganskogo rudnogo rayona. [HISTORY OF GEOLOGICAL AND EXPLORATORY INVESTIGATIONS IN THE DZHEZGAZGAN MINERALIZED AREA]: Izvestiya, Akad. Nauk KazSSR, ser. geol. vyp. 2 (35).

167. Kalyuzhnyy, V.A., Problema genezisa nefti i gaza Timano-Pechorskoy neftegazovoy provintsii. [PROBLEM OF THE ORIGIN OF OIL AND GAS IN THE TIMAN-PECHORA PETROLEUM AND GAS PROVINCE]: Sov. geol., no. 11.

168. Kayupov, A.K. and S.Sh. Seyfullin, Nekotoryye zakonomernosti proyavleniya orudneniya na Dzhezkazgane. [CERTAIN REGULARITIES OF MINERALIZATION IN DZHEZKAZGAN]: Izvestiya, Akad. Nauk KazSSR, ser. geol., vyp. 2 (35).

169. Kopystyanskiy, R.S., Osnovnyye voprosy klassifikatsii treshchin v neftyanoy geologii. [PRINCIPAL PROBLEMS OF CLASSIFICATION OF FRACTURES IN PETROLEUM GEOLOGY]: Dopovidi, Akad. Nauk URSR, no. 10.

170. Kormilitsyn, V.S., Osnovnyye cherty mezozoyskoy metallogenii Vostochnogo Zabaykal'ya. [MAIN FEATURES OF MESOZOIC METALLOGENY OF EASTERN TRANSBAYKALIYA]: Sov. geol., no. 11.

171. Kochetov, M.N., K voprosu uproshcheniya tekhniki podscheta zapasov nefti i gaza. [ON SIMPLIFICATION OF THE TECHNIQUE OF CALCULATING OIL AND GAS RESERVES]: Geol. nefti i gaza, no. 12.

172. Krasil'nikov, B.N. and Ya.G. Kats, Znacheniye zon treshchinovatosti dlya poiskov neftyanykh zalezhey i nekotoryye voprosy neftenosnosti Minusinskoy kotloviny. [SIGNIGICANCE OF JOINTING IN SEARCH FOR OIL DEPOSITS AND CERTAIN PROBLEMS OF PETROLEUM OCCURRENCE IN THE MINUSINSK BASIN]: Izv. vyssh. uchebn. zaved., ser. geol. i razvedka, no. 9.

173. Kuzin, M.F., Opyt primeneniya biogeokhimicheskogo metoda dlya posikov redkometal'nykh mestorozhdeniy. [AN EXPERIMENT IN THE USE OF BIOGEOCHEMICAL PROSPECTING METHODS TO THE SEARCH FOR RARE METAL DEPOSITS]: Razv. i okhrana nedr, no. 11.

174. Kulikov, B.F., Nakhodka blekloy rudy v sul'fidno-magnetitivykh rudakh Kacharskogo

mestorozhdeniya. [DISCOVERY OF GRAY COPPER ORE IN THE SULFIDE-MAGNETITE ORES OF THE KACHARA DEPOSIT]: Zap. Vses. min. o-va, ch. 88, vyp. 6.

175. Kunayev, D.S., Nekotoryye osobennosti geologicheskogo stroyeniya rudnykh zalezhey rayona Pokro-Yugo-Zapad mestorozhdeniya Dzhezkazgan. [CERTAIN PECULIARITIES OF THE GEOLOGIC STRUCTURE OF ORE DEPOSITS IN THE POKRO-YUGO-ZAPAD AREA OF THE DZHEZKAZGAN MINERALIZED REGION]: Izvestiya, Akad. Nauk KazSSR, ser. geol., vyp. 2 (35).

176. Lugov, S.F., Mezozoyskiye granitoidy Chukotki i svyaz's nimi orudneniya. [MESOZOIC GRANITOIDS OF CHUKOTKA AND THE RELATED MINERALIZATION]: Sov. geol., no. 10.

177. Lyapichev, G.F. and L.A. Miroshnichenko, Ob"yedinennaya nauchnaya sessiya po problemam razvitiya proizvoditel'nykh sil Tsentral'nogo Kazakhstana. [COMBINED SCIENTIFIC MEETING ON THE PROBLEMS OF DEVELOPMENT OF THE ECONOMIC RESOURCES OF CENTRAL KAZAKHSTAN]: Izvestiya, Akad. Nauk KazSSR, ser. geol. vyp. 2 (35).

178. Maksimov, S.P., A.I. Ivanov and V.A. Kirov, Usloviya formirovaniya zalezhey nefti i gaza v paleozoyskikh otlozheniyakh blizhnego Saratovskogo Zavolzh'ya. [CONDITIONS OF FORMATION OF PETROLEUM AND GAS DEPOSITS IN THE NEARER SARATOV TRANS-VOLGA REGION]: Geol. nefti i gaza, no. 12.

179. Maleyev, Ye.F., Perspektivy poiskov perlita v Zakarpat'ye. [POSSIBILITIES OF FINDING PERLITE IN TRANSCARPATHIA]: Razv. i okhrana nedr, no. 11.

180. Maslov, Yu.S., Osnovnyye osobennosti obrazovaniya nekotorykh tipov zolotorudnykh mestorozhdeniy. [MAIN FEATURES OF FORMATION OF CERTAIN TYPES OF GOLD DEPOSITS]: Razv. i okhrana nedr, no. 11.

181. Monich, V.K. and A.N. Nurlybayev, Nefelinovyye porody Yuzhnogo Kazakhstana kak vozmozhnyye alyuminiyevyye rudy. [NEPHELINE ROCKS OF SOUTHERN KAZAKHSTAN AS POSSIBLE ALUMINUM ORES]: Izvestiya, Akad. Nauk KazSSR, ser. geol., vyp. 2 (35).

182. Nikitin, N.M., O rasprostranenii zalezhi gipsov v Tul'skoy oblasti. [THE DISTRIBUTION OF GYPSUM DEPOSIT IN THE TULA REGION]: Sov. geol., no. 11.

183. Nuralin, N.N., O roli treshchinnoy tektoniki v rudootlozhenii v Dzhezkazgane. [THE ROLE OF FRACTURE TECTONICS IN MINERALIZATION IN DZHEZKAZGAN]: Izvestiya, Akad. Nauk KazSSR, ser. geol., vyp. 2 (35).

184. Nurlybayev, A.N. and V.K. Monich, O novom mestorozhdenii dyumort'yerita Ushtobe v Severo-Zapadnom Pribalkhash'ye. [A NEW DUMORTIERITE DEPOSIT AT USHTOBA IN THE NORTHWESTERN BALKHASH REGION]: Vestn, Akad. Nauk KazSSR, no. 10.

185. Oganisyan, Sh.S., Opyt primeneniya gravimetrovoy s"yemki pri poiskakh i razvedke slepykh kolchedannykh rudnykh tel alaverdskogo tipa. [AN EXPERIMENT IN THE USE OF GRAVIMETRIC SURVEYS IN THE SEARCH FOR CONCEALED SULFIDE ORES OF THE ALAVERDY TYPE]: Doklady, Akad. Nauk SSSR, t. 29, no. 4.

186. Ogiyenko, V.S., Raspredeleniye broma v kamennoy soli Angaro-Lenskogo solyanogo basseyna i vozmozhnost' nakhozhdeniya kaliynykh soley. [DISTRIBUTION OF BROMINE IN THE ROCK SALT OF THE ANGARA-LENA SALT BASIN AND THE POSSIBILITY OF DISCOVERING POTASSIUM SALTS]: Geokhimiya, no. 8.

187. Smirnov, V.I., Metallogeniya sinskladchatykh i sinorogennykh intruziy Bol'shogo Kavkaza. [METALLOGENY OF INTRUSIVES OF THE GREATER CAUCASUS SYNCHRONOUS WITH FOLDING AND OROGENY]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

188. Sokolov, I.P., Ye.K. Kan, N.M. Rozanov and I.A. Shmelev, O napravlenii dal'neyshikh geologopoiskovykh i razvedochnykh rabot na neft' i gaz v Ferganskoy vpadine. [PLAN FOR FURTHER GEOLOGICAL EXPLORATION FOR OIL AND GAS IN THE FERGANA BASIN]: Geol. nefti i gaza, no. 12.

189. Sokolova, N.T. and V.V. Korolev, Okolozhil'nyye izmeneniya kvartsevykh porfirov, svyazannyye s redkometal'nym orudeneniyem. [NEAR-VEIN ALTERATION OF RHYOLITES RELATED TO RARE METAL MINERALIZATION]: Geokhimiya, no. 8.

190. Fomin, V.M. and N.A. Marinov, O kompleksnosti geologicheskoy i gidrogeologicheskoy s"yemok. [ON THE COMPLEXITY OF GEOLOGICAL HYDROGEOLOGICAL SURVEYS]: Razv. i okhrana nedr, no. 11.

191. Fridman, A.I., Geologiya i geokhimiya prirodnykh gazov Urupskikh mednokolchedannykh mestorozhdeniy (Severnyy Kavkaz). [GEOLOGY AND GEOCHEMISTRY

OF NATURAL GAS AT THE CHALCOPYRITE DEPOSITS OF URUPA (NORTHERN CAUCASUS)]: Izv. vyshch. ucheb. zaved., ser. geol. i razvedka, no. 9.

192. Khutorov, A.M., O persepktivakh poiskov nefti i gaza v Ferganskoy doline. [OIL AND GAS POSSIBILITIES IN THE FERGANA VALLEY]: Sov. geol., no. 10.

193. Tsimel'zon, I.O., Primeneniye gravimetrii dlya pryamykh poiskov nefti i gaza. [GRAVIMETRY APPLIED DIRECTLY TO THE SEARCH FOR PETROLEUM AND GAS]: Geol. nefti i gaza, no. 12.

194. Chernov, V.M., Ob usloviyakh obrazovaniya Kostamukshskogo zhelezorudnogo mestorozhdeniya. [CONDITIONS OF FORMATION OF THE KOSTAMUKSHA IRON DEPOSIT]: Izv. Karel'sk. i Kol'sk. fil Akad. Nauk SSSR, no. 3.

195. Shilina, G.P. and S.M. Tseytlin, O pervoy nakhodke kimberlitov na Aldane. [THE FIRST FIND OF KIMBERLITES IN ALDAN]: Sov. geol., no. 10.

196. Shpil'man, I.A., Usloviya formirovaniya Bol'shekinel'skogo vala i perspektivy poiskov nefti i gaza v prilegayushchikh rayonakh. [CONDITIONS OF FORMATION OF THE BOL'SHEKINEL' SK BRACHYANTICLINE AND THE GAS AND OIL POSSIBILITIES IN THE ADJACENT REGIONS]: Geol. nefti i gaza, no. 12.

HYDROGEOLOGY, ENGINEERING GEOLOGY

197. Glushkova, M.I. and P.G. Grigorenko, Prirodnyye usloviya Batkenskoy vpadiny i perspektivy ispol'zovaniya yeye podzemnykh vod. [NATURAL CONDITIONS IN THE BATKENSKAYA BASIN AND THE POSSIBILITIES OF UTILIZATION OF ITS GROUND WATERS]: Izv. Akad. Nauk KirgSSR, ser. yestestv. i tekhn. nauk, t. 1, vyp. 2.

198. Grave, N.A., Osnovnyye cherty i zakonomernosti razvitiya tolshch merzlykh porod na kraynem severo-vostoke Azii. [PRINCIPAL FEATURES AND REGULARITIES OF DEVELOPMENT OF THE SEQUENCES OF FROZEN ROCKS IN THE EXTREME NORTHEAST OF ASIA]: Izvestiya, Akad. Nauk SSSR, ser. geol., no. 6.

199. Zaytsev, I.K., Osnovnyye tipy gidrogeologicheskikh struktur na territorii SSSR. [MAIN TYPES OF HYDROGEOLOGICAL STRUCTURES IN THE USSR]: Sov. geol. no. 11.

200. Zargaryan, Ye.L., Plastovyye vody mestorozhdeniya Karachukhur-Zykh. [RESERVOIR WATERS OF THE KARACHUKHUR-ZYKH OIL FIELD]: Geol. nefti i gaza, no. 12.

201. Kudelin, B.I., K voprosu o paleogidrogeologicheskikh usloviyakh nakopleniya presnykh vadoznykh vod v Dneprovsko-Donetskom artezianskom basseyne. [ON THE PALEOHYDROGEOLOGICAL CONDITIONS OF ACCUMULATION OF FRESH VADOSE WATER IN THE DNEPR-DONETS ARTESIAN BASIN]: Sov. geol., no. 10.

202. Lomtadze, V.D., Rezul'taty issledovaniy vody, otzhatoy iz glinistykh otlozheniy razlichnoy stepeni litifikatsii. [RESULTS OF INVESTIGATION OF WATER EXTRACTED FROM ARGILLACEOUS SEDIMENTS OF DIFFERENT DEGREES OF LITHIFICATION]: Izv. vyshch. uchebn. zaved., ser. geol. i razvedka, no. 9.

203. Mavritskiy, B.F., Kratkiy analiz temperaturnykh izmereniy v skvazhinakh Zapadnoy Sibiri. [A BRIEF ANALYSIS OF BOREHOLE TEMPERATURES OF WESTERN SIBERIA]: Razv. i okhrana nedr, no. 11.

204. Mavritskiy, B.F., O geotermicheskikh usloviyakh Zapadno-Sibirskogo artezianskogo basseyna. [GEOTHERMAL CONDITIONS IN THE WEST SIBERIAN ARTESIAN BASIN]: Doklady, Akad. Nauk SSSR, t. 129, no. 5.

205. Smolina, L.B. and L.Ye. Bronovitskaya, Vliyaniye okislennykh burykh ugley i lignina na fol'tratsiyu vody cherez lёssovyye grunty i gliny. [THE EFFECT OF OXIDIZED BROWN COAL AND LIGNIN ON THE PERCOLATION OF WATER THROUGH LOESS AND CLAYS]: Doklady, Akad. Nauk UzSSR, no. 10.

206. Shagoyants, S.A., K voprosu o podschete zapasov presnykh gruntovykh vod v zasushlivykh rayonakh. [CALCULATION OF FRESH GROUND WATER RESERVES IN ARID REGIONS]: Sov. geol., no. 11.

B. Papers in "Materialy", "Trudy", "Uchenyye Zapiski" and "Sborniki"

1. Geologicheskoye Stroyeniye i Neftegazonosnost' Vostochnykh Oblastey Ukrainy, [Geological Structure and Petroleum in the Eastern Regions of the Ukraine, Kiev]: 1959, 440 pp. From the contents: Bondarchuk, V.G., V.B. Porfir'yev and V.Ya. Klimenko, Work of the Academy of Sciences Ukrainian SSR on the geology of Ukrainian petroleum deposits. Klitochenko, I.F., Summary of geological exploration for oil

and gas in the Ukrainian SSR in 1951-1955 and the trend of this work in 1956-1960. Porfir'yev, V. B., Modern ideas on the origin of petroleum and of its economic accumulations in the Carpathians. Chirvinskaya, M. V., Summary of geophysical exploration of petroliferous regions in 1951-1955 and pland for 1956-1960. Kozlov, A. L., Modern principles of exploitation of gas fields and the methods of geological exploration for gas. Glushko, V. V., I. F. Klitochenko, I. Yu. Lapkin and M. V. Chirvinskaya, Tectonics of the Ukraine. Babintsev, A. Ye., Saline waters of the Russian platform in connection with its further petroleum possibilities. Klimenko, V. Ya., Structure of the Dnepr-Donets basin and the conditions of formation of its petroleum and gas deposits. Bilyk, A. A., L. S. Palets and S. Ye. Cherpak, Results of geological exploration for oil and gas in the Dnepr-Donets basin and on the margins of Donbas in 1951-1955 and the direction of further investigations. Usenko, I. S., Composition, structure and stratigraphy of the basement of the Dnepr-Donets basin. Shul'ga, P. L., New data on the Middle Carboniferous stratigraphy of the Dnepr-Donets basin. Lapchik, F. Ye., Permian and triassic deposits of Donbas and the Dnepr-Donets basin. Kaptarenko-Chernousova, O. K., Sequence of development of Mesozoic foraminifera in the Dnepr-Donets basin and the northwestern margin of Donbas. Yamnichenko, I. M., Stratigraphy and facies of Jurassic deposits of the Dnepr-Donets basin and the margins of Donbas. Sterlin, B. P., New data on Triassic, Jurassic and Lower Cretaceous stratigraphy and facies of the Donets folded zone, the Dnepr-Donets graben and their juncture. Timofeyeva, N. M., Summary of seismic surveys in the Dnepr-Donets basin and the western margin of Donbas. Vidomenko, Kh. R., Geological map of the Dnepr-Donets basin. Stefanenko, A. Ya., Main features of tectonics, history and petroleum accumulation of the Pripyat' downwarp. Golubtsev, V. K., G. I. Kedo, A. S. Makhnach and A. V. Fursenko, Paleozoic stratigraphy of the Pripyat' downwarp. Pistrak, R. M., S. V. Tikhomirov, Devonian and Carboniferous rocks of the Pripyat' downwarp and their petroleum possibilities. Sudarikov, Yu. A., Structure of the Salo-Ergen' upland. Kutsyba, A. M., Stratigraphy, facies, paleogeography and oil possibilities of the Devonian strata in the Dnepr-Donets basin. Bliznyuk, V. F., Results of structural-exploratory drilling (detailed and profile) in the northwestern margin of Donbas. Litvinov, V. R., Geological characteristics of the zone of salt structures of the cryptodiapyr type and of structures not pierced by salt. Sharapov, I. S., On the search for Devonian petroleum in the Dnepr-Donets basin and the Pridonets marginal downwarp. Bernadskaya, L. G., Paleozoic volcanism in the Dnepr-Donets basin. Zabelin, V. N. and Arsiriy, Yu. A., Concerning the geologic structure of the Radchenko oil and gas deposit. Martynov, A. A., Certain regularities of structure of the Paleogene and Mesozoic deposits of the eastern part of the southwestern border of the Dnepr-Donets basin. Khot'ko, Zh. P. and B. V. Bondarenko, Main geological results and problems of geophysical investigations in the Pripyat' basin. Vitenko, V. A. and Ye. I. Vul'chin, Stratigraphy and history of development of the Chernigov outlier of crystalline rocks in Devonian time.

2. Geokhimicheskiye Metody Poiskov Neftyanykh i Gazovykh Mestorozhdeniy, [Geochemical methods of prospecting for oil and gas]: Moscow, 1959, 462 pp. Contents: Saukov, A. A., Migration of the elements and geochemical prospecting methods. Sokolov, V. A., Scientific basis of the geochemical methods of prospecting for petroleum and gas. Mogilevskiy, G. A., On the nature of geochemical anomalies and the rational method of their discovery. Silin-Bekchurin, A. I., Movement of deep underground waters. Gurevich, M. S., The significance of geochemical zonation of ground waters in search for oil. Yasenev, B. P., Results and effectiveness of gas surveys. Yurovskiy, Yu. M., Development of gas logging in the USSR. Krems, A. Ya., G. G. Grigor'yev and A. S. Medvedev, An experiment in geochemical prospecting in the Timan-Pechora petroliferous province. Petrov, V. I., Summary of gas surveys in Western Siberia. Petersil'ye, I. A., Application of geochemical methods to an investigation of the natural gas occurrence in the intrusive massifs of Kola peninsula. Kortsenshteyn, V. N., Mechanism of formation of gas deposits in Stavropol'ye. Geller, Ye. M., Geochemical clues to natural gas in the rocks overlying gas deposits. P'yankov, N. A., Vertical migration of gas. Rimskiy-Korsakov, Ye. V., Surface gas survey — a method of prospecting for native sulfur. Glebovskaya, V. S., Gas survey in search for ore deposits. Subbota, M. I., The content of heavy gaseous hydrocarbons in gases of surficial origin. Yuranek, Yu., Results of geochemical investigations in search for petroleum and gas in Czechoslovakia. Stegena, A., Geochemical method of locating faults. Shneerson, V. B., The role of surface phenomena in petroliferous beds and their use in prospecting for oil and gas. Gurevich, M. G., Chemical composition of gases in rocks and the processes of formation hydrogen and hydrocarbons in nature. Kozlov, V. P. and G. A. Gladysheva,

An experiment in geochemical logging in the Bakhmut basin. Elinson, M.M., Apaplication of gas surveys to coal deposits. Ozolin, B., Sampler for investigation of gases dissolved in water. Mishnina, T.A., Comparison of different methods of extracting gases dissolved in natural waters. Sokolov, V.A., Gas analysis technique and apparatus and the ways of improving them. Turkel'taub, N.M. and Zhukhovitskiy, A.A., Chromatographic methods of gas analysis applied to geochemical methods of investigation in the oil and gas industry. Gurevich, M.G., Methods and apparatus for gas and analysis used in geochemical prospecting for oil and gas. Elinson, M.M., Gas analyzer for rapid analysos of hydrocarbons in natural gas. Mogilevskiy, G.A., Basic problems of microbiological methods of prospecting for petroleum and gas. Kuznetsov, S.I., Basis for microbiological methods of prospecting for oil and gas. Mekhtiyeva, V.L., Microbiological characteristics of Tertiary deposits of Ciscaucasia. Lyukhter, A., Search for petroleum in Poland with the aid of microbiological methods. Shvartz, A., Microbiological methods of searching for oil. Alekseyev, F.A., Radiogeochemical method of prospecting for oil and gas. Yermakov, B.I., L.P. Kuz'mina, M.G. Ovanesov and Yu.A. Romanov, Geochemical investigation of radiometric anomalies over Shpakovo and Koshkimbet petroleum deposits. Yermakov, V.I. and M.G. Ovanesov, Certain regularities in the intensity variation of gamma radiation of the earth's surface in petroliferous regions. Gol'bek, G.R. et al., Radiometric apparatus for prospecting for oil and gas. Zolotov, A. V. and M.S. Yefimova, Results of radiometric investigations in the oil fields of Bashkiriya. Bishir, D.P., Gon, Ye.F. and Ye.M. Nikulesku, Results of radiometric investigation in search for petroleum in Rumania. Florovskaya, V.N., Luminescence-bituminological method of prospecting for petroleum. Botneva, T.A., The effect of gas deposits on the bitumen content in the overlying beds. Kolpenskiy, G.P., Application of fluorescent microscopy to the investigation of bitumens in rocks. Yelizarova, Ye.N., Luminescence-bituminological surveys. Starobinets, I.S. and A.Ya. Gavrilova, The significance of bituminological investigations in geochemical prospecting. Moyse, I.I., An experiment in the application of the luminescence-bituminological method on the Slatvorele structure (Rumania). Ronov, A.B., Organic carbon in the sedimentary rocks of the Russian platform. Andreyev, P.F., Appraisal of oil possibilities on the basis of the data on the properties of dispersed organic matter. Al'tovskiy, M.Ye., Organic matter and microflora of ground waters and their significance in appraising the possibility of occurrence of gas and oil. Yurganov, N.N., On the influence of organic carbon of sedimentary rocks on the oxidation-reduction conditions of their formation as illustrated by the upper and middle Miocene deposits of Sakhalin. Dvali, M.F., Geochemical investigations in the complex of investigations in the complex of investigations of oil possibilities in new regions. Kovda, V.A. and P.S. Slavin, Geochemical anomalies in soils of petroleum deposits. Kozin, A.N., Geochemical subdivision of the Kuybyshev, Orenburg and Ul'yanov districts in connection with appraisal of their petroleum possibilities. Krotova, V.A., Hydrogeological criteria of the presence of petroleum. Bars, Ye.A., Hydrogeochemical investigations in prospecting for oil and gas (present state and problems). Gurevich, M.S., On hydrogeochemical methods of search for oil and gas. Shugrin, V.P., Salt and gas composition of ground waters as an indicator of the presence of petroleum and gas. London, E.Ye., Evaluation of petroleum ·d and gas possibilities in the Dnepr-Donets basin on the basis of hydrogeochemical investigations. Kovalev, V.F., Prognosis of gas and oil possibilities of the Transuralian region on the basis of hydrogeological hydrochemical data. Il'ina, Ye.V., Vertical hydrochemical zonation of ground waters and gas and hydrochemical indicators of the presence of oil and gas in the Verkhoyansk downwarp and Vilyuy basin. Gatal'skiy, M.A., Methods of hydrogeological evaluation of petroleum possibilities of regions under investigation as illustrated by the Russian platform. Baleyanu, F.D., A trial of the hydrogeochemical prospecting method. Gavrilenko, Ye.S., The hydrogeological basis for prospecting for petroleum on the Russian platform. Dubil'yer, A.S., The significance of subsurface run-off in establishing the presence of oil and gas in a region. Kogon, S.S., The pattern of distribution of calcium chloride waters in the central part of the Russian platform in connection with its geological structure.

3. Gidrokhimicheskiye Materialy, [Hydrochemical materials]: V. 29, Moscow, 1959, 295 pp. From the contents: Posokhov, Ye.V., Hydrochemistry of waters in the alluvium of some of the Central Kazakhstan valleys. Burkser, Ye.S., V.V. Burkser and B.B. Zaydis, Mineral water in the town of Khmel'nik, Vinnitsk district. Levchenko, V.M. and P.V. Denisov, The origin of the composition of water of the alkaline thermal waters at Altyn-Arasan.

4. Zadachi i Perspektivy Poskovo-Razvedochnykh Rabot na Neft' i Gaz v Zapdnykh

Rayonakh Sredney Azii, [Problems and Prospects of Exploration for Petroleum and Gas in the Western Regions of Middle Asia, Askhabad]: 1959, 382 pp. From the contents: Mirchink, M. F., The main problems of development of geological exploration for petroleum and gas in the western regions of Middle Asia. Denisevich, V. V., Geological structure and oil and gas prospects of Turkmenia and the urgent problems of prospecting and exploration. Abdullayev, Z. A., The effectiveness of geophysical methods of prospecting in the study of the deep structure of the western regions of Middle Asia and a plan for geophysical surveys. Zhukovskiy, L. G., The state of geological prospecting for oil and gas in the northeastern part of Turkmenian SSR and Western Uzbekistan. Smirnov, L. N., Geological structure and oil and gas prospects of the southeastern Turkmenistan. Kalugin, P. I., The oil and gas prospects of the Mesozoic deposits of Turkemanina SSR. Gavrilov, A. Ya., Characteristics of distribution and structure of petroleum deposits in the Pliocene rocks and the rational method of their exploration and exploitation. Luppov, N. P., Structure and paleogeography of the western part of Middle Asia. Kurbatov, V. S., Geological structure and mineral resources of Turkmenian SSSR, Ryabchinskiy, G. Ya., Main features of hydrogeology of the Turkmenian SSR in connection with the problem of water supply for the producing and prospective oil fields. Forsh, N. N., The current state of the problem of subdivision of redbeds in Western Turkmenia. Nevolin, N. V., Geological structure of Ustyurt and a plan for future geophysical work. Semenovich, V. V., The state of exploration and development of the Cheleken deposit and the possibilities of production of petroleum. D'yakov, B. F., Geologica structure and petroleum prospects of Mangyshlak peninsula. Popov, G. I., Stratigraphy of the Apsheron deposits in the petroliferous regions of Western Turkmenia. Nazarov, N. O., Mud volcanos of the petroliferous regions of the southwestern Turkmenistan and the problem of their investigation. Brod, I. O., Work of the Complex Southern Geological Expedition of the Academy of Sciences USSR in Turkmenistan in1956. Bakirov, A. A., Regional tectonic basis for the search for new large petroleum and gas regions in Turkmenian SSR. Shirokov, A. S., Preliminary results of geophysical work by the Ministry of Geology and Conservation of Mineral Resources in the western part of Middle Asia.

5. Zapiski Leningradskogo Gornogo Instituta, [Transactions of the Leningrad Mining Institute]: v. 40, Moscow, 1959, 165 pp. From the contents: Tatarinov, P. M., Achievements of Soviet geologists in the development and investigation of the mineral raw materials of the USSR. Twenty first Meeting of KPSS. Stulov, N. N. and I. I. Shafranovskiy, Crystallography and mineralogy in the Leningrad Mining Institute. Solov'yev, S. P., Contributions to petrology by the scientists of the Leningrad Mining Institute. Shafranovskiy, I. I., Crystallography, mineralogy and petrography in "Zapiski Leningradskogo Gornogo Instituta". Shafranovskiy, I. I., Present state of the problems of dependence of the outward form of a crystal on its internal structure. Nikitin, V. D., Present state of the problem of pegmatization.

6. Materialy po Geologii i Poleznum Iskopayemym Tsentral'nykh Rayonov Yevropeyskoy Chasti SSSR, [Materials on geology and economic mineral deposits of the central regions of European part of the USSR]: Vyp. 2, Kaluga, 1959, 242 pp. Contents: Leonenko, I. N., Present state of knowledge of the Kursk magnetic anomaly (KMA) and the plan for further investigations. Dobrokhotov, M. N., V. D. Polishchuk and Yu. S. Zaytsev, On the stratigraphy of the Kursk metamorphic series. Yepifanov, B. P., Problems of Precambrian stratigraphy of the Kursk-Voronezh dome. Chaykin, S. I., New data on the geology and structure of the crystalline basement of the Belgorod iron region. Rusinovich, I. A., Zone of supergene alteration of Precambrian rocks and the origin of iron ores of the KMA. Kalinin, I. P., Certain problems of geological structure of the L'gov-Mikhaylov iron region of the KMA and some urgently needed investigations. Rusinovich, I. A., The Gostishchev deposit of rich iron ore. Rakhmanov, V. P., The distribution of some secondary minerals in the sedimentary and residual rich iron ores of the Yakovlev deposit, KMA. Illarionov, A. A., Structural characteristics of the ferruginous quartzites of the Mikhaylov deposit, KMA. Plaksenko, N. A., Classification of the ferruginous quartzites of the KMA and the chemical method of their correlation. Kulibaba, F. V., Some data on the hydrogeological and engineering-geological conditions in the northern part of the KMA. Popov, I. V., Certain engineering-geological problems in the study of the deposits of the KMA. Slavyanov, V. N. and V. I. Fandeyeva, On the method of prediction of the engineering-geological conditions of stripping and mining of the KMA deposits. Shmidt, N. G., Geophysical investigations of the KMA. Kopayev, V. V., Regional magnetic anomalies in the KMA and adjacent areas. Pavlovskiy, V. I. andI. A. Zhavoronkin, The object of further geophysical investigation

in the Belgorod iron region. Pavlovskiy, V.I., On the possibility of determination of the vertical thickness of dense sedimentary rocks by variometry. Borodulin, M.I., Seismic investigation of the KMA sedimentary sequence.

7. Nauchnyye Soobshcheniya Instituta Geologii i Geografii Akademii Nauk LitSSR, [Scientific communications of the Geological and Geographical Institute, Academy of Sciences LitSSR]: V. 10, vyp. 1, Vilno, 1959, 113 pp. From the contents: Garbalyauskas, Ch. A., V.K. Gudelis and V. K. Klimavichene, On the activity of marine silts.

8. Sbornik Rabot Tsentral'noy Geologorazvedochnoy Ekspeditsii Geologicheskogo Upravleniya Tsentral'nykh Rayonov Glavgeologii RSFSR, [Collection of Works of the Central Geological Exploration Party of the Geological Office of the Central Regions, Chief Geological Office, RSFSR]: Vyp. 4, Moscow, 1959, 242 pp. From the contents: Grokhovskiy, L.M., Thenardite lakes of the northern Aral region. Prints, R.N., Brick clays of the Gur'yev district, KazSSR. Perkin, V.D. and Ye. A. Shilovskaya, Relations between physical properties and textural characteristics of limestones. Pichugin, M.S., Results of investigation of Upper Carboniferous deposit of the Oka-Klyaz'ma region in connection prospecting for dolomite. Lobanova, N.F., Hydrochemistry of ground waters and salt lake brines in the area of the Dzhaksy-Klych deposit in the Aral region.

9. Trudy VNIGNI, [Trans. All-Union Institute for Research in Petroleum Geology]: vyp. 15, Moscow, 1959, 213 pp. Contents: Burshtar, M.S., Petroleum prospects in Georgia. Buleyshvili, D.A. and Ye. K. Vakhaniya, Stratigraphic chart of the Tertiary rocks of Georgia. Vakhaniya, Ye. K., The age of the Uplistsikha oyster beds. Vakhaniya, Ye. K., Stratigraphy and petroleum possibilities of the Maykop formation in Georgia. Okrochedlidze, D.P., The Tarkhan zone of Megreliya. Buleyshvili, D.A. and G.V. Dzhaparidze, Geological structure and petroleum prospects of the Tbilisi region. Vakhaniya, Ye. K., G.N. Nikuradze, D.M. Abesadze and K.I. Gegelidze, Possible petroleum occurrences in the Mesozoic of Western Georgia. Dzvelaya, M.F., Petroleum prospects of Guriya. Kitovani, Sh.K., The problem of petroleum migration through the Mesozoic Lok and Khram crystalline massifs (Georgian SSR). Chikovani, A.A. Tectonics of the northern periphery of the Imeretinsk Range in connection with petroleum possibilities. Davrisheva, T.A., Gases of the Sarmatian deposits of Southern Kakhetiya. Shatirishvili, T.M., Petrography of Cenomanian analcime-bearing tuffaceous rocks of the Rachi region (W. Georgia). Shatirishvili, T.M. and Z.A. Imnadze, Lithological and microfaunal description of the Cretaceous rocks of the Kolkhida plain (based on cores from deep boreholes. NPU Gruzneft'). Chubinishvili, K.G., Petrography of the conglomerates of the Dzveli-Anaga region (Kakhetiya).

10. Trudy VNIGNI, [Trans. All-Union Institute for Research in Petroleum Geology]: Vyp. 23, 222 pp. Contents: Bratash, V.I., Organization of prospecting for petroleum in the Yakkobag region. Rozanov, N.M. and B.S. Antonov, Petroleum prospects in the Mesozoic of the Fergana valley. Kan, Ye.K. and G.M. Aladatov, New data on geologic structure and oil and gas prospects of the northern part of Fergana (Narynsk road). Sokolov, I.P. A.M. Khutorov and G.I. Grachev, Petroleum in the Tertiary deposits of Fergana valley. Zhukovskiy, L.G., Yu.V. Kayesh and K.A. Sotiriadi, Petroliferous Jurassic and Cretaceous facies of the Bukhara-Khiva petroliferous province. Semenovich, V.V., Conditions of formation of folds in Pliocene and post-Pliocene complexes of the West-Turkmenian lowland. Shvarts, T.V., History of folding in the Pribalkhash region. Bratash, V.I., A.S. Sokolov-Kochegarov and G.I. Khasina, The problem of pre-Paleogene folding in the Tadzhik depression. Kalinko, M.K., Types of oil and gas traps in the Mesozoic section of the western part of Middle Asia. Amanov, S., Reservoir properties of sandy and silty rocks of the Akchagyl' stage in Western Turkmenia. Sinitsin, F.Ye., Tertiary rocks of the Iliy basin. Saidov, M.N., A.V. Kuchapin and V.P. Mokin, Tertiary rocks of the southern Caspian shore. Zagoruyko, V.A. and I.V. Skvortsov, Paleogene deposits of Western Aral region. Belyakova, G.M., Some results of investigation of pelecypod fauna from the Upper Cretaceous of the lower waters of the Amu Dar'ya River. Rudik, V.A., Lithology and petrography of the Lower Cretaceous deposits as illustrated by the Kul'kamysh, Derbent and Gaurdak sections (southwestern ranges of the Gissar Range). Luppov, N.P., Lower Cretaceous stratigraphy of the southwestern ranges of the Gissar Range. Il'in, V.D., Upper Cretaceous stratigraphy of Western Uzkekistan and the adjacent regions of Turkmenia.

11. Trudy VNIGRI, [Trans. All-Union Geological Research Institute]: Vyp. 140, Leningrad, 1959, 387 pp. Contents: Dedeyev, V.A., Stratigraphy of Devonian deposits of the Shchuch'insk synclinorium (eastern

slope of Polar Urals). Kareva, Ye. A., Upper Paleozoic and Lower Mesozoic of the eastern slope of Polar Urals and the western part of West Siberian lowland. Derviz, T.L., Jurassic stratigraphy of the middle course of the Irtysh and Ob' rivers and the Chulym-Yenisey basin. Mesezhnikov, M.S., Jurassic stratigraphy of the eastern slope of the pre-Polar and Polar Urals. Kravets, V.S., Jurassic deposits of the Uvat-Tobol'sk region. Voronkov, Yu.S., Cretaceous of the pre-Polar Urals. Galerkina, S.G., Upper Cretaceous and Tertiary stratigraphy of the Berezovka-Malo Atlym region. Gribkov, V.V., On the age of the continental deposits of the Kizak River (Tymen' district). Fol'ts, A.A., Quaternary stratigraphy of the northwest of the West Siberian lowland. Balabanova, T.F., et al., Mesozoic-Cenozoic facies in the western part of the West Siberian lowland. Ivanova, Ye.N., Argillaceous Mesozoic and Cenozoic rocks of the southwestern part of the West Siberian lowland. Nalivkin, V.D., Tectonics of the Mesozoic-Cenozoic deposits in the west of the West Siberian lowland. Kruglikov, N.M., Hydrogeological conditions of the Berezovka region. Sverchkov, G.P., Petroleum occurrences in the western part of the West Siberian lowland. Korneyeva, V.G., V.V. Ansimov and L.M. Kravchenko, Combined petroleum exploration and prospecting work in the west of the West Siberian lowland.

12. Trudy Gosudarstvennogo Vsesoyuznogo Issledovatel'skogo i Proyektnogo Instituta "Giprovostokneft'", [Trans. of the All-Union State Research and Planning Institute, "Giprovostokneft'"]: Vyp. 2, Moscow, 1959, 442 pp. From the contents: Kapishnikov, A.L., Main results of research at the Giprovostokneft' Institute. Yelistratova, T.Ya., Devonian deposits of the Mukhanovsk area. Fadeyev, M.I., Stratigraphy of the Lower Carboniferous terrigenous deposits of the Kuybishev Povolzh'ye. Fadeyev, M.I., Certain peculiarities of composition of the sandstones in the Lower Carboniferous terrigenous sequence of the Kuybishev Povolzh'ye. Fadeyev, M.I., The Cherepet zone of the Kuybishev Povolzh'ye. Frolova, Ye.K., Ratoffkite in the Lower Kazanian beds of the Kuybishev Povolzh'ye. Fadeyev, M.I., Content and distribution of some trace elements in the Lower and Middle Carboniferous rocks of the Kuybishev region. Frolova, Ye.K., Terminology of the limestone-dolomite-magnesite series of carbonate rocks. Fadeyev, M.I., Contributions to the stratigraphy of the petroliferous part of the Carboniferous series at the Krasnyy Yar deposit. Fadeyev, M.I., Nomenclature of the oil-bearing beds of the Volga-Urals petroliferous province. Kozin, A.N., A review of the composition and salinity of the Carboniferous and Devonian brines in the oil fields of the Kuybishev Povolzh'ye. Kozin, A.N., Vertical hydrogeochemical zonation of the Kuybishev Povolzh'ye and the petroleum prospects based on hydrogeochemical data. Kozin, A.N., Geochemistry of bromine and iodine in the ground waters of the Volga-Urals region (as illustrated by the Kuybishev Povolzh'ye region). Ashirov, K.B., Conditions of formation of oil deposits in the Kuybishev Povolzh'ye. Berezina, M.D., Preparation of petroleum for ash extraction for spectrographic studies. Mzhachikh, K.I., On the genesis of sulfurous asphalts and asphaltites of the Orenburg district. Mzhachikh, K.I., Certain problems of metamorphism of petroleum in the reservoir. Sazonov, B.F., Some results of development of the Samarskaya Luka deposit. Surguchev, M.L., A brief analysis of mining and flooding of the coal-bearing zone at the Pokrovskoye deposit. Sazonov, B.F., Certain regularities of flooding of oil-bearing beds.

13. Trudy Gosudarstvennogo Nauchno-Issledovatel'skogo Instituta Gornokhimicheskogo Syr'ya, [Trans. of the State Institute for Research in Mineral Chemical Materials]: Vyp. 5, Moscow, 1959, 320 pp. Contents: Gimmel'farb, B.M., Principal geological regularities of distribution of phosphorites in the USSR. Krasil'nikova, N.A., Phosphorites of the Katanga basin. Kurman, I.M., Certain problems of lithology of the Cambrian and Ordovician rocks of the Baltic region. Plotnikova, V.I. and A.I. Smirnov, Phosphorites of the Seleuk deposit. Tushina, A.M., Phosphatization of the Upper Cretaceous iron ores of Eastern Pre-Urals. Narchemashvili, O.V., Some data on stratigraphy and phosphatization of the Cretaceous deposits of Dagestan. Gimmel'farb, B.M., Some problems of exploration and calculation of phosphorite reserves. Uflyand, Ts.I., Trukhacheva, A.G. and A.I. Smirnov, Formation of industrial ores at the Ak-Say phosphorite deposit. Sokolov, A.S., Geological pattern of structure and distribution of native sulfur deposits. Sakharova, M.S. A.G. Trukhacheva, Mineralogical and petrographic study of sulfur ores. Otreshko, A.I., Structural pattern and distribution of the sulfur deposits of the Middle Volga. Virovlyanskiy, G.M., Certain problems of post-ore tectonics of hydrothermal deposits. Virovlyanskiy, G.M., Certain problems of structural analysis of hydrothermal deposits. Otreshko, A.I., Comments on Gimmel'farb's paper: "Classification of phosphorite deposits".

14. Trudy Dal'nevostochnogo Politekhnicheskogo Instituta, [Transactions of the Far Eastern Polytechnical Institute]: V. 54, vyp. 1, Vladivostok, 1959, 121 pp. Contents: Buriy, I. V., Triassic stratigraphy of Southern Primor'ye. Denisova, T. A., Ripple marks in the Dobrotovo deposits in the pre-Carpathian region. Denisova, T. A., Subaqueous slumping in the Miocene deposits of the pre-Carpathian region. Oktyabr'skiy, A. T., Igneous rocks of Mt. Pereval'naya in Southern Primor'ye. Oktyabr'skiy, A. T., Leucite absarokites of the middle course of the San-Pauza River. Finashin, V. K., Ores and the enclosing rocks of the Mopaus tin deposit. Zimin, S. S., On the origin and practical importance of the Belousov phosphorites in Kuznetskiy Alatau. Dotsenko, L. I., Limestones of the southern part of the Far Eastern Primor'ye. Ovsyannikov, N. V., Mechanical properties of andesites and basalts as a function of their geological and petrographic characteristics.

15. Trudy Instituta Ogneuporov, [Trans. of the Refractories Institute]: Vyp. 28, Leningrad, 1959, 230 pp. From the contents: Slesarevich, V. V. and M. G. Suvorova, The Inaglinsk dunite deposit in Southern Yukutiya.

16. Trudy Instituta Okeanologii AnSSR, [Trans. Oceanographic Institute, Academy of Sciences USSR]: V. 33, Moscow, 1959, 209 pp. From the contents: Mokiyevskaya, V. V., Geochemistry of iron in sea water. Zaytseva, Ye. D., Volume of cation exchange between the sediments of the Far Eastern seas and the northwestern part of the Pacific Ocean. Shishkina, O. V., Chemical composition of the mud waters of the Pacific. Starikova, N. D., Organic matter of the liquid phase of the sediments in the northwestern part of the Pacific. Shishkina, O. V., Sulfates in the mud waters of the Black Sea. Volkov, I. I., Determination of various sulfur compounds in marine sediments.

17. Trudy Laboratorii Vulkanologii Akad. Nauk SSSR, [Trans. Volcanological Laboratory of the Academy of Sciences USSR]: Vyp. 17, Moscow, 1959, 191 pp. Contents: Marenina, T. Yu., Volcano Khangar in the Central Range of Kamchatka. Markhinin, Ye. K., Volcanos of Kunashir Island. Tokarev, P. I., Connection between volcanic and seismic activities in the Kuril-Kamchatka zone. Maleyev, Ye. F., Basic principles of classification of pyroclastic rocks.

18. Trudy Nauchno-Issledovatel'skogo Instituta Geologii Arktiki, [Trans. of the Research Institute of Arctic Geology]: V. 105, Leningrad, 1959, 170 pp. Contents: Urvantsev, N. N., Problem of the gas occurrences in the ore deposits of the northwestern part of the Siberian platform. Vasilevskaya, N. D., Mesozoic stratigraphy and flora of the Sangar coal-bearing deposits in the Lena coal basin. Sobolevskaya, R. F., New data on Cambrian stratigraphy of Central Taymyr. L'vov, K. A., Proterozoic and Lower Paleozoic stratigraphy of the pre-Polar and Polar Urals. Saks, V. N., Tectonic development of the Khatanga depression in the Mesozoic era. Voronov, P. S., M. T. Kiryushina, Ya. I. Pol'kin and S. A. Strelkov, Recent tectonics of the trans-polar part of the Lena-Yenisey region. Gor, Yu. G. and A. I. Ivanov, On the early phases of basaltic and alkalic ultra basic volcanism of the northern part of the Siberian platform. Gol'dburt, T. A., Meymichites of the Gulinsk intrusion. Liberzon, V. Z., New data on granitic intrusions of the eastern part of the Anabar shield. Dundo, O. P., Quaternary deposits of the upper basin of the Velikaya River. Zhizhina, M. S., Significance of tabulate corals for the stratigraphic subdivision of the Silurian deposits of Eastern Taymyr.

19. Trudy Ural'skogo Politekhnicheskogo Instituta, [Trans. of the Uralian Polytechnic Institute]: Coll. 82, Sverdlovsk, 1959, 167 pp. From the contents: Chebukov, M. F. and N. Starinskaya, An investigation of the effect of the mineralogical composition of clays and of the physical properties of the carbonate component on the process of clinker-formation in the raw Portland cement mixtures. Zlatkin, S. G. and Gur'yev, F. V., Okulovsk clay deposit as a source of raw ceramic material for the Sverdlovsk ceramic combine. Zhilin, A. I. and Yu. D. Kruchinin, On the method of studying crystallization of slag. Kurchinin, Yu. D., Dependence of the strength of slags on structure. Mamykin, P. S. and N. V. Zinov'yeva, Refractory and ceramic properties of materials in the system: chromite-alumina.

20. Uchnehyye Zapiski LGU, No. 278, ser. fiz., i geol. nauk, [Scientific Notes of the Leningrad State University, No. 278, Physical Sciences and Geology]: Vyp. 11, Leningrad, 1959, 264 pp. From the contents: Mironov, V. S., Gravity anomalies of Rudnyy Altay and their geological significance. Sveshnikov, G. B. and M. K. Dorofeyeva, Certain electrochemical characteristics of sulfides.

21. Uchenyye Zapiski Saratovskogo Universiteta, t. 72. vyp. Geogr., [Scientific Notes of the University of Saratov]: V. 72, Geography issue, Saratov, 1959, 87 pp. From the contents: Zhuteyev, S. A., Buried valley of Pontus - Volga within the lower Transvolga region. Kuzin, V. P., Dynamics of slumpin in the lower Volga region. Leont'yev, G. I., Modern crustal movements and fluctuation of level of the Caspian Sea.

CHRONICLE

AT THE INTERNATIONAL SYMPOSIUM ON VOLCANOLOGY[1]

by

M. Favorskaya and V. Kigay

In accordance with the resolution of the International Volcanological Association and at the request of the UNESCO, a symposium on applied volcanology was held at the Sorbonne in Paris, September 16 to 19, 1959, to discuss the following subjects: 1) prediction of the time, place and character or eruptions and prediction of the direction of lava flows and glowing avalanches and methods of controlling them; 2) application of geophysical methods to volcanology; 3) utilization of volcanic energy for practical purposes and the scientific results obtained during relevant investigations; 4) recommendations and rules for prevention of injury, death and property damage during catastrophic eruptions; and 5) establishment of danger zone boundaries.

The symposium was attended by representatives of Belgium and the Belgian Congo (6 delegates, Holland (1), Iceland (1), Italy (2), New Guinea (1), Portugal (1), the U.S.A. (1), the Philippines (1), France (15), Switzerland (1) and Japan (4). The Soviet Union was represented by ten delegates, eight from the Laboratory of Volcanology, Academy of Sciences, U.S.S.R. (Professor V.I. Vlodavets, leader), and two from the Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry (M.A. Favorskaya and V.A. Kigay).

Most of the papers dealt with methods of predicting volcanic eruptions. Many authors extended their remarks beyond the scope of thisproblem and gave detailed descriptions of volcanic activity in various active volcanic regions. For example, the delegate from Iceland, S. Thorarinnson, exhibited maps showing the distribution of active volcanoes on the island and characterized eruptive activity and the accompanying gaseous emanations. He described great short lived torrents caused by the melting of ice by the eruptions and the copious liberation of sulfurous gases causing mass mortality among birds.

Several papers were devoted to active volcanism in the Belgian Congo. M. Denaeyer described a volcano whose crater contains a lava lake about 8 km in diameter communicating with the magmatic chamber. It is interesting that at present this lake, which has existed for 50 years, emanates water-free gases, while the Hawaiian lava lake has been liberating water at approximately the same rate throughout its existence. This is explained by the location of the first volcano in the middle of a continent and of the second on an island where sea water has access to the magma chamber.

The methods of prediction of volcanic eruptions were discussed in a series of papers by Soviet and foreign scientists. Seismic observations and observations of variation in the activity of fumaroles, of temperature changes, and of changes in the angle of slopes were mentioned.

G.S. Gorshkov reported on seismic investigations at the Kamchatka Volcanological Station. His observations show that eruption follows the strongest shock. E. Berg, who studied seismic phenomena accompanying eruptions to the north of Lake Kivu (Belgian Congo), came to the same conclusion. The paper by G. Taylor (of New Guinea) aroused considerable interest. In addition to seismic observations, he proposed considering the cyclic nature of eruptions and their connection with tidal forces and meteorological phenomena. He illustrated his statement by citing the predictions made by him for the volcano on Monam Island. During the discussion a heated argument arose as to the possibility of predicting the path of a glowing avalanche.

Besides reports of this type, there were also reports of purely methodological character.

[1] Na mezhdunarodnom simpoziume po vulkanologii.

The paper by R. Fabre and M. Chaigneau (France) dealt with the technique of sampling and analysis of fumarolic gases. The report by Delibré and a group of French scientists discussed the determination of absolute ages of certain lava flows of the Auvergne. The question of protection of population from the consequences of volcanic eruptions was discussed in the papers by V.I. Vlodavets, "The principles of delimiting volcanic districts in the U.S.S.R.;" by A.A. Caraz (Philippines), "Thoughts on public safety during volcanic eruptions;" and by J. Neumann van Padang (Holland), "Measures for insuring safety of population from the consequences of volcanic eruptions."

As a result of discussion of the papers, it was resolved that permanent volcanological stations (observatories) be established in the immediate vicinity of active volcanoes, that seismic methods be accepted as best for the prediction of eruptions and that arrangements be made for determining danger zones near active volcanoes and evacuation from such zones in close cooperation with local administrations in case of threatening eruption.

Besides the papers mentioned above, there were papers by F. Penta (Italy) on "Natural steam (endogenic power), state of investigation and ideas"; by S. Thorarinnson, "Investigation and exploitation of natural fuel in Iceland"; and by B.I. Piyp, "Problems of utilization of the energy of volcanic hot waters in the Kamchatka-Kuril Island arc".

Colored films of eruptions in Central Africa and Hawaii were shown at the symposium. Skillful photography presented these natural phenomena very vividly and the films left a strong impression.

From September 13 to 15 geological excursions were made to the Central Massif of France (Auvergne). The excursions were led by Professor L. Glangeaud of the Sorbonne, who spent 25 years in the study of this region. Glangeaud was assisted during the excursions by his young associates, Moreau, Baubier and Lemonier. The methods of paleovolcanic investigations were discussed during the excursions and illustrated by examples of solutions of paleovolcanic problems. The organization of the excursions was excellent: each participant was supplied with a guide book, geological maps and sections of the entire region and the localities to be visited, and with reprints of geological works on the region. Even en route Glangeaud continued his explanations.

The first day was spent at Mt. Dore. This Pliocene volcano, whose flows are older than the Puy flows, is a complex cone with 120 craters. Here rhyolitic flows predominate over basaltic. It is believed that two primary magmas existed beneath the volcano: a palingenetic granitic-rhyolitic magma formed at the depth of 12-15 km during the Alpine orogeny and a gabbroic-basaltic magma which rose from the depths of the crust. The eruptions of basaltic magma occurred from the Oligocene to the middle Miocene; and of the siliceous magma, from the Miocene to the middle Pliocene. Mixing of the two magmas produced hybrid lavas, erupted in the Pliocene.

The Puy de Sancy, the highest point of the Mont Dore volcanic group, is also a complex volcano with about 40 craters. The peak is composed of a series of flows and dikes of different ages, some of which cut through the lower flows but not the upper. The base of the volcano is granite. On the Sancy flows there are several younger parasitic cones. Six domes of this peak are composed of trachyandesite and phonolite. The crater of Puy de Sancy has been destroyed by erosion, which lowered the volcano by 700 m. Now the volcano is a system of ridges and plateaus separated by glaciated valleys now being filled with alluvium. The summit of Puy de Sancy is at 1886 m.

The valleys reveal the structure of the volcano, consisting of numerous alternating horizontal flows of andesite and trachyandesite, beds of volcanic ash, cinders, "nuees ardente" deposits and explosion breccias.

The andesites and trachytes in the middle of the section are middle Pliocene. The upper flows of Sancy are trachyandesites (sancyites and doreites). The volcanic complex is cut by a number of large and often quite long faults. Some of the faults contain groups of dikes, and other faults cut the dikes. The dikes are well exposed in the precipitous sides of the domes, together with well preserved small eruptive centers filled with pyroclastic material.

According to the local geologists, in addition to the linear dikes, the dome contains numerous radial and ring dikes (cone sheets). Chains of Quaternary cones lie along the faults cutting the Mt. Dore flows. The main, northwest trending fault begins at the summit of the volcanic complex and passes through its slope; in the north, the Bourboule volcanic complex lying on this fault has been lowered 400 m.

In the region of La Bourboule, numerous thermal springs with medicinal properties are localized in the continuation of the fault trending northwest from Puy de Sancy. Along the fault a sequence of thin-bedded redeposited ash, containing Miocene diatoms and freshwater sponge spicules, comes in contact with granite, exhibiting excellently preserved slickenside surfaces.

We visited the summit of Puy de Dome. Long ago a spine of Peléan type surmounted the dome and then collapsed. Near the summit there are ruins of a Roman temple of the II Century B.C. Paleomagnetic investigations of the ruins have shown that the stones for the structure were imported from the neighboring volcaño Pierre-Zou.

The chain of the puys and the adjacent area, especially the Quaternary cones, are clearly visible from the balcony of the meteorlogical station on top of Puy de Dome. Here, as at the summit of Puy de Sancy, observation is aided by a well prepared panoramic map of the region mounted in the balustrade of the round tower gallery. The distribution of the chains of volcanic cones of different ages reflects successive changes in the trend of the faults.

On the volcanic plateau of Gergovie, we examined the well preserved vents of the ancient Oligocene volcanoes. The intrusion and extrusion of basalts of the ancient Gergovie volcano was accompanied by the formation of peculiar subaqueous deposits, peperites interbedded with Oligocene (Stampian) limestones. A sequence of younger limestones overlies the ancient volcanic deposits and is overlain by green clays of Aquitainian age and by Burdigalian basalts.

The excursion continued to the Limagne plain and the Forez Mountains, a horst bordered in the west by a chain of Oligocene and younger volcanoes. At one point along an extensive fault a quarry was examined which reveals a part of an Oligocene basaltic flow covered with peperite and dikes of Miocene basalts containing xenoliths of Oligocene rocks. The last investigator of the region, Baubier, successfully applied the paleomagnetic method to separate basalts of very similar chemical composition but of different ages. The geological excursion ended with the examination of this quarry.

During the excursion we examined a number of carbonate thermal springs (Royat, La Bourboule and others) of the Auvergne region, classical examples of carbonate thermal waters genetically related to early Tertiary volcanism. Glangeaud has repeatedly emphasized the localization of thermal springs in deep fault zones. At La Bourboule resort we saw a large normal fault along which thermal waters have been tapped by boreholes.

On September 12 we visited the Mineralogical Museum at the Institute of Natural History. Our guide was Prof. B. Gèze. The museum occupies a large well furnished building and contains rich collections of minerals and rocks from almost all countries (but mainly from the French colonies). It was founded by Haüy and expanded and systematized by Lacroix. A mineralogical laboratory is attached to the museum.

Of very great interest besides the main mineralogical collection is a large collection of meteorites from different parts of the globe, including the great Sahara meteorite. There is also a collection of models based on experimental reproduction of the shapes of tektites and polished sections of iron meteorites. There are also special collections illustrating structures and textures of rocks, and a small lithological-stratigraphic collection of fossiliferous rocks.

Remarkable in their beauty and variety are collections of decorative stones including blue, rose and black agates from the Rio Grande and polished chalcedony of all shades from colorless to black.

In the systematic mineralogical collection the epidote group is very well represented (black epidotes from Alaska, different allanites and piedmontites), as well as polychrome tourmalines from France and Madagascar, some of the crystals 50 cm long and from 4 to 5 cm across. Very effective are dioptase druses, bright green smithsonite and large crystals of smaragdite in gabbro.

But on the whole, the main mineralogical exhibit is considerably inferior to the collections in our large museums (the Mineralogical Museum of the Academy of Sciences and the Mining Institute Museum in Leningrad), especially so far as phosphates, sulfates and sulfides are concerned.

We also visited Prof. Orcel's mineralogical laboratory, a teaching and research center where museum collections are used in working mainly in the fields of mineral genesis, experimental mineralogy and petrography.

At present Dr. Court's laboratory is investigating the structure of a phenomenal quartz crystal several meters in length with well developed cleavage and unusually high specific gravity. In the thermal laboratory, investigations are carried out by three methods (thermal analysis, dilatometry and heating) in various gases in vacuo in an apparatus constructed in the laboratory. Special studies are being made on the reflectivity of ore minerals in different parts of the spectrum. For this purpose an extensive collection of polished sections is used arranged according to metals and regions.

The petrographic laboratory founded by Lacroix continues its work under the direction of Yeremina (Jeremine). It contains a unique collection of thin sections, chemical analyses of igneous and metamorphic rocks of the world and numerous sections of meteorites. We visited Lacroix's room where he worked after his retirement. It contains a collection of objects picked up after the eruption on Martinique: fused coins, bent burnt forks and nails,

crumpled and fused utensils. Investigation of these objects made it possible to determine the temperature of the glowing avalanche which descended on the town. The collection includes many bombs from various volcanoes.

Foreign scientists are very much interested in our scientific literature and are trying to establish and organize scientific communication. G. Macdonald of the University of Hawaii has initiated translation of all bulletins of the Volcanological Station and proceedings of the Volcanological Laboratory into English. The articles from "Tufelavy" (Proc. Laboratory of Volcanology Academy of Sciences U.S.S.R., No. 14, 1957) have been translated into French. This collection of papers on one subject is well known abroad. It occurs to the writer that publication of such collections would be a very convenient way of acquainting foreign scientists with our work.

Many volcanologists — S. Thorarinson (Iceland); R. Morimoto, G. Yokoyama, Schimozuru, A. Aramaki (Japan; Macdonald (USA); Aubert de la Rue and G. Tazieff (France) — have expressed a strong desire to become acquainted with the volcanoes of the U.S.S.R.

As a result of the successful work of the symposium, several important scientific problems have been brought nearer to solution and a number of interesting scientific contacts established.